Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

PRICE 50 CENTS

MARCH 1956

DYNAMIC "FAIL SAFE"

ALSO IN THIS ISSUE

Roller Speed-Matching Systems

A Process Panel Analog Teaches Operators

Hydraulic vs. Pneumatic Power Controls

Control ENGINEERING

MARCH 1956

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

PRINT ORDER THIS ISSUE 29,584

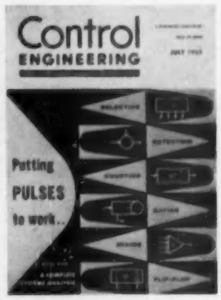
SHOPTALK

A CHALLENGE TO READERS

Our pyrotechnic cover and the related article deal with one of those "Why Didn't I Think of It?" innovations. This one, we believe, has broad implications, offering, as it does, a new, positive way to reduce the fallibility of "fail-safe" systems to near zero. When we first got wind of it we asked our crack analyzer, Ed Kompass, to dig for "bugs". Ed dug . . . and dug . . . but soon could be heard muttering, "Now why didn't I think of this?" Just what is the new approach to "fail-safe"? You had better turn to page 79 to find out. And after you've read the article we would welcome any letters that suggest either A) a "bug" in the concept, or B) an unusual application for the new technique. If you're in the first category, we'll ask the inventors to try to resolve your objection. If you're in the latter, then with your permission, we'll publish your sketch and details on the application. Send your letters to Ed Kompass at this office.

PUTTING COVERS TO WORK

Last July we succumbed to the do-it-yourself rage with a cover showing how pulses can be used. Readers were so enthusiastic that Tony Blundi of Burroughs converted the cover and his article into a working display at the Western Computer Conference.



The Exhibit . . . and its Inspiration

HAROLD STIRS UP A SWARM

We've been told that the control business in greater Los Angeles simulates a giant bee hive. Poke the hive and you'll stir up a swarm of busy activity. Dip inside and you'll find mucho honey. Our Western editor, Harold Hood, keeps busy testing this theory. Two proofs of the swarm and honey are in this issue: the feature news story—livened with Harold's candid pictures—which tells how ElectroData has brought in a honey of a digital crop in two years. And *Industry's Pulse*, which swarms with facts on how the L. A. control hive got the way it is.

● Manufacturing ●● Manufacturing and product development ●●● Manufacturing, product development and research □●● Pilot manufacturing, product development and research

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
●●●	●●	●●	□●●	●●	●●●		●●	●●●	●●	●●	●●	●●●	Precision Mechanics, Optical Devices, Ceramics
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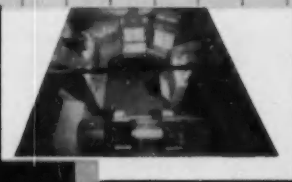
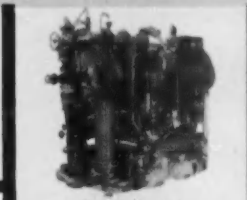
●●●			●●●	●●●	●●●	●●●				●●●		●●●	SYSTEMS ENGINEERING

Librascope Desk-Size Computer

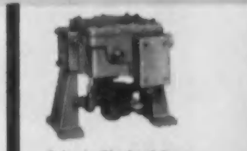


Link Aviation F-89D Jet Simulator

GPL Industrial-Institutional TV System



Griscom-Russell Shipboard Distilling Plant



Askania Electro-Jet Power Package

SYSTEMS ENGINEERING

The GPE Companies are leaders in that small, select group in American industry which is broadly qualified to develop and produce the systems needed today for defense and industry. GPE leadership accounts for some of the most advanced systems in use in business, television, aviation, marine, steel, oil, power and other industrial fields.

In Systems Engineering, advanced capacities and resources are prerequisite. Yet, no matter how highly advanced, they are insufficient if limited to a few areas. And beyond that, success requires the application of such *balanced competences* at every stage—beginning with research and extending all the way through development, production, and final testing.

The following basic characteristics and methods of operation of the GPE Companies explain GPE successes in systems work:

- *the exceptional engineering acumen of more than 2500 GPE scientists, engineers and technicians working in depth in the wide range of advanced capacities indicated in the chart above;*
- *the extensive research, development, manufacturing and testing resources of the GPE Companies;*
- *the GPE operating policy, Coordinated Precision Technology, which inter-relates all relevant GPE engineering, research, and production skills and resources;*
- *unremitting insistence on highest quality on the part of every GPE Company, every step of the way.*

No GPE Company is limited by the boundaries of its own specialties. Behind each engineering group working on a specific problem in one GPE company stands the whole group of GPE scientists, engineers and technicians with the answers—or the knowledge that will find the answers—to questions underlying and related to that problem.

To the customers of GPE Companies this means that the concept and development of equipment, components and systems are not restricted or distorted by traditional allegiance to specific competences. The five systems illustrated, while products of different GPE companies, are all examples of the consistent application of balanced competences, achieved through GPE coordination.

For brochure describing GPE Coordinated Precision Technology and the work of the GPE Companies, or help on a specific problem, write: General Precision Equipment Corporation, 92 Gold Street, New York 38.

GENERAL PRECISION EQUIPMENT CORPORATION

THE GPE PRODUCING COMPANIES

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- II INTERNATIONAL PROJECTOR CORPORATION
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- IV GENERAL PRECISION LABORATORY INCORPORATED
- V THE GRISCOM-RUSSELL COMPANY
- VI LINK AVIATION, INC.
- VII SHAND AND JURS CO.
- VIII THE HERTNER ELECTRIC COMPANY
- IX THE STRONG ELECTRIC CORPORATION
- X J. E. McAULEY MFG. CO.
- XI ASKANIA REGULATOR COMPANY
- XII AMPRO CORPORATION
- XIII LIBRASCOPE, INCORPORATED

FEEDBACK

THE PROBLEM FORUM . . .

. . . went on the road this month. Scouring the Deep South for trends, developments, and feature articles that will, in time, appear in the magazine, your forum chairman came upon some interesting problems that should challenge the members of the forum. Challenge 1 appears below.

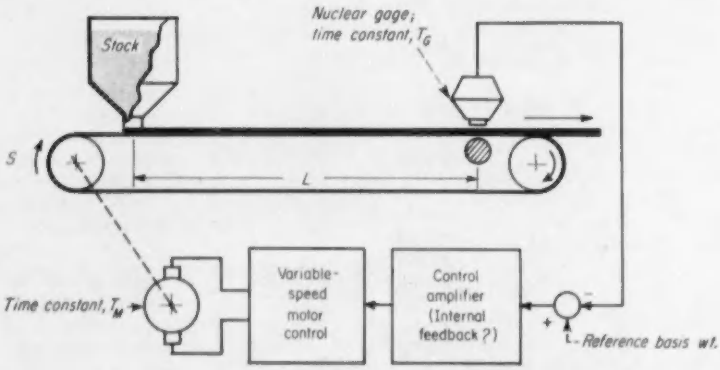
Remember to send in problems and answers. The authors of published problems will receive the complete file of answers plus cash enough for a tankful of gasoline (no auxiliary tanks, though). Contributors of solutions will be able to fill 'er up, too.

Challenge I

The modern cigarette machine makes cigarettes as continuous rods. A "carding" roll pulls tobacco out of a hopper onto a strip of cigarette paper carried by a belt. The machine wraps the cigarette paper around the tobacco and the resulting rod passes between the source and the ionization chamber of a nuclear gage. The accompanying sketch represents the composite transportation lag of all the elements in the process by a belt traveling at velocity, *S*, through a distance, *L*. The gage compares the basis weight of the cigarette rod with the reference basis weight. Any difference is amplified to vary the operating speed of the entire machine and so correct the basis weight.

$L/S = T_L$, the transportation lag; T_M = the time constant of the variable speed motor; and T_G = the time constant of the gage, approximately ½ sec (determined principally by the gage's noise filter). The unfortunate situation: $T_L >> T_M > T_G$.

If the machine operates incorrectly for 5 sec, it will disgorge about 20 ft of off-tolerance cigarette rod, or the equivalent of four and one half packs. How can the control engineer reduce the duration and extent of the deviations? The gage, by the way, cannot be relocated because of the machine's configuration, and the manufacturer is not about to redesign the machine this year. Design a feedback circuit for the control amplifier. Remember that T_L is much greater than any of the transfer lags in the system. Should the feedback circuit within the amplifier be arranged positive or negative?



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Seeking, throws a bouquet

To the Editor—

In the *Feedback* section of your December 1955 issue, I have read about an interest in correspondence courses, and/or course outlines and training aids for small groups desiring information on automatic control at a professional level. I certainly would like to take such a correspondence course, and also attend such group sessions. At the least I would appreciate an outline and bibliography to progress through.

Personally, my needs are for a more profound knowledge of the higher mathematics involved.

I believe Control Engineering is doing a most magnificent presentation, and especially appreciate the article in the August, 1955 issue, *These 7 Steps Design a Tach Stabilized Servo* by Jules Kadish, and the one in the December, 1955 issue, *How Stabilization Improves Closed-Loop Operation* by Davidson & Nashman.

Albert C. Ghizzoni
West Paterson, N. J.

Industrial engineering magazines are predicated on the desires of engineers to progress in their jobs by keeping up with the latest techniques and equipment in their fields. Many of these engineers are not trained in the disciplines of the mathematical tools involved. It therefore becomes the responsibility of the magazine that serves them to introduce them to the mathematics and to break down the design procedures into the logical "handbook-type" steps laid out in the Kadish and the Davidson-Nashman articles. We shall publish many more of these working-man's articles and shall, in each one, trace the steps through the practical system design problems. Ed.

Credit in arrears

Mr. Max D. Miller, G. M. Giannini and Co., Inc., Pasadena, Calif., suggested in the *Feedback* section of our January, '56 issue a **technique for testing rate gyroscopes.** It appeared on page 9 under our heading, "Another way to skin a cat". We did not credit Mr. Miller for his useful kink. **Know all ye by these presents that he is the contributor. Ed.**

Readers piqued in Ind., Pa., and U. K.

Three readers, from as many corners within our circulation's reach, were aroused to comment on the geometrical essay presented by Morton Mathew and Frank Bradley in the

FEEDBACK

Problem Forum of our November issue. The piqued:

G. Duckworth, S. Woodford, London, England, submitted an algebraic proof obtained from considering the five roots of the complex equation

$$z^5 = j = exp \frac{(j\pi)}{2}.$$

George E. Row, 644 E. 22nd St., Indianapolis, Ind., took time off from his next day's work to shuffle the equations of an algebraic proof and then went on to develop a geometric proof, complete with triangle constructions and Q. E. D. If only space permitted the publication of his fine treatise.

Joseph D. E. Konhauser, Haller, Raymond and Brown, Inc., State College, Pa., offered the briefest:

TO THE EDITOR—

I enjoyed reading Morton Mathew's elegant proof of the identity *sin 54° − sin 18° = ½*. The shortest proof, using identities, that I have been able to come up with follows:

$$\begin{aligned} &\sin 54^\circ - \sin 18^\circ \\ &= 2\cos \tfrac{1}{2}(54^\circ + 18^\circ)\sin \tfrac{1}{2}(54^\circ - 18^\circ) \\ &= 2\cos 36^\circ \sin 18^\circ \\ &= \frac{2\cos 36^\circ \sin 18^\circ \cos 18^\circ}{\cos 18^\circ} \\ &= \frac{\cos 36^\circ \sin 36^\circ}{\cos 18^\circ} \\ &= \frac{\frac{1}{2}\sin 72^\circ}{\cos 18^\circ} \\ &= \tfrac{1}{2}. \end{aligned}$$

Reader gets in his slugs

TO THE EDITOR—

I would like to compliment Mr. Davidson and Mr. Nashman on their excellent article, *Putting Stabilization to Work*, in the January issue of CONTROL ENGINEERING.

The article did, however, have an error in the illustrative problem on page 83. In the equations $\omega_n = \sqrt{K/J}$ and $T_m = J/F$, the units of J should be in slug-in.^{2}, not lb-in.^{2}. This means that the rotor inertia of the Kearfott R110 servomotor, given as 1.13×10^{-6}, would be divided by 384. This accounts for g, required to get correct and consistent units throughout the problem.

Melvin H. Lerman
The W. L. Maxson Corp.
New York City

Right. The computed values in the balance of the problem are correct as published, but the correct use of g was not shown in the derivation of these answers. Ed.

MULTI-CHANNEL
DATA REDUCTION
SYSTEM

Punch Card Unit:
IBM #523 Gang Summary Punch
is shown at left

18-Channel Simultaneous Sampling System reduces voltage data into magnetic tape and IBM punched-cards

The EPSCO DATRAC 'C' System simultaneously samples and converts 18 bipolar input voltages into their numerical representation and stores the resultant digital codes on a magnetic tape. Up to 750,000 individual data points may be stored on a single 10½" reel of magnetic tape. The incoming data may be visually monitored during the data run. Following the data run, the DATRAC 'C' System transfers the information from the magnetic tape on to IBM punched cards. In operation, the system is entirely automatic; although provision is made for both manual control and synchronization to an external timing source. Further, the DATRAC 'C' System automatically checks the accuracy of the data as it is being transferred from the magnetic tape to the punched cards.

MAJOR DESIGN FEATURES:

- **Extensive use of magnetic circuit elements**
- **Chopper stabilized input amplifiers**
- **Standard cell automatic internal reference**
- **Conservative computer type circuit design**

Suitable for a wide variety of applications, this system has the following outstanding features:

1. ***Input full scale voltages*** .... *Multiple ranges from ±10 mv full scale to ± 1000v full scale*
2. ***Overall system:***
   Relative accuracy *0.025%*
   Absolute accuracy *0.05%*
3. ***Effective sampling time for 18 input channels*** .... *0.25 microseconds*
4. ***Number of data points per second*** .... *Up to 180*
5. ***Tape Coding*** .... *Sign and 4 decimal digits in 8-4-2-1 binary decimal code with parity check and sprocket pulse.*
6. ***Information content for each magnetic tape block or IBM punched card*** .... *One complete set of 18 readings plus frame number*
7. ***Magnetic tape output*** .... *Either single block or continuous*

EPSCO INCORPORATED

588 Commonwealth Ave., Boston 15, Mass.

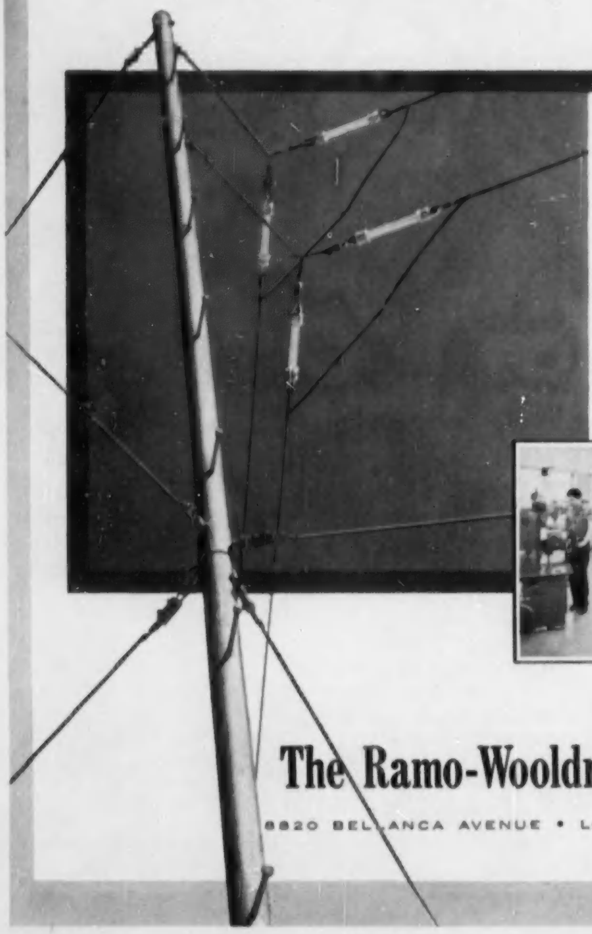
Write for literature on Model "C" DATRAC System

SEE US AT THE WALDORF DURING THE NEW YORK I.R.E. SHOW MARCH 19-22

ADVANCED Communications

The design of modern communications equipment involves much more than electronic circuit techniques. Keyboards and coders are often required to translate the intelligence to be transmitted into "machine language." Recording and reproducing devices store intelligence until the equipment is ready to transmit it, or hold received intelligence until it can be translated back into human language by a printer or other output display device.

The combination of such mechanical and electromechanical techniques with the better known but still developing techniques of electronic circuit design makes of modern communications a much broader field than is commonly recognized. When such technical tools are used to provide equipment tailored to our rapidly improving understanding of propagation phenomena and information theory, the resulting practical improvements in communication are sometimes little short of spectacular.



The growing communications activities of The Ramo-Wooldridge Corporation have generated requirements for additional physicists and engineers with substantial experience in research, development, or production engineering on advanced airborne and ground-based...

- Communication, Navigation and ECM Systems
- HF, VHF, and UHF Transmitters and Receivers
- Precision Electro-Mechanical Equipment
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- Video and Pulse Circuitry
- Miniaturization and Packaging

Part of Communications Equipment Pilot Production Activities

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A CONTROL PERSONALITY

L. A. UMANSKY
puts a drive on progress

A man who has pioneered a technology is asked a great many foolish questions about how and why it got where it is today. Leonid A. Umansky faces this inevitable barrage with quiet good humor. "Progress in control?" he muses. "Progress is a fleeting target. It is what is latest and what is newest. Today we are preoccupied with the continuizing of machine operations—we call it 'automation'. But yesterday this was our preoccupation, too. It's all a matter of degree, of steady advances, of properly trained men. This technology has not sprung up like Jack's beanstalk. It is a product of Evolution."

Soft-spoken Mr. Umansky modestly ignores one thing: that Evolution has always had its "prime movers"—dedicated, oriented enthusiasts like himself, who speed up and lend luster to progress.

A computer in '22

L. A. Umansky's career as a "prime mover" started in 1919, when he joined the General Electric Test Program after four years in this country as a member of an Artillery Commission for the Russian Ordnance Dept. His excellent mathematical training, which went with an Electrical Engineering degree from the Polytechnic Institute of St. Petersburg, sped him into the work for which he was to become famous: the use of analytical techniques in applying controlled power to industrial processes. Progress for the young engineer—and for control—started immediately. In 1920 he developed a formula—used to this day—to calculate partial stabilization of flywheel m-g sets for mine hoists. And in '22 (he beams in recollection) he went into a busy steel mill to make oscillographic tests of a reversing drive and wound up developing a mechanical computer for the root mean square of current.

This brief foray into steel-making launched Umansky into twenty years of control application work in that industry. Between '27 and '40 he was awarded 18 patents on basic advances in controlled power. He promoted the use of dc motors with adjustable potential control to provide flexible power for heavy processes. And he was one of the first to appreciate and apply the amplidyne, and later the amplistat, to regulating systems.

After working in American mills, Umansky was sent abroad to survey practice in western Europe and between '30 and '32 helped General Electric to engineer some of the huge steel mills that sprouted in the U.S.S.R. during its first five-year plan. He returned to the U.S. in 1933 and in '36 took charge of the company's steel mill section. During the war Mr. Umansky led the engineering groups that contributed to the building of giant electrochemical plants, aircraft factories, and the huge electrical power systems for nuclear plants at Oak Ridge and Hanford. After the war, as Manager of the Industrial Engineering Dept., he instituted unusual engineer training courses in regulating systems and application engineering. And created, guided, and spurred on to its first successes a dynamic analysis group that aimed at the basic study and control of industrial processes (see January 1956 issue, pages 18-19).

Last August 1, L. A. Umansky retired after 36 years with General Electric. Although he enjoys his new leisure, this vigorous, articulate man is still far from retired as a "prime mover" in his chosen field. "No, I have no plans at the moment. I delight in spending more time at home with my wife, Claudia, and with the many books and publications in science and engineering which I had little time to read in the past. I imagine this 're-education' I am now going through may whet my interest in many things." And we imagine that the control field will continue to hear from Leonid A. Umansky.

WHAT'S NEW

A 2-yr-old Places 3rd in Digital Sweepstakes

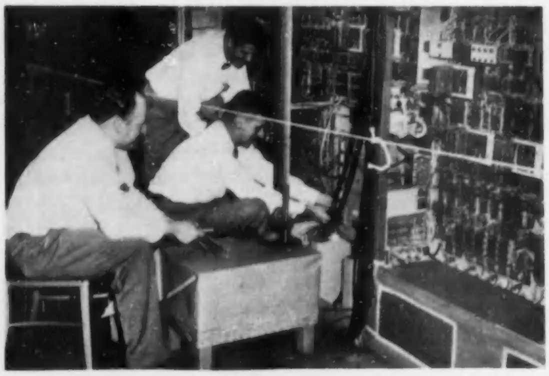
ElectroData's recent dedication of a new 40,000-sq-ft plant and computer center served notice that this prodigy of the digital business now moves in the company of giants. Current production is three systems a month—but plans call for a doubled capacity by 1957.

PASADENA, CALIF., Dec. 13, 1955 —To most of the reporters and local dignitaries who milled through ElectroData's handsome new plant this day, it was just another spectacular example of the way control-field companies seem to sprout and grow in this smog-tinted climate (see *Industry's Pulse*, page 55). But to those steeped in the folklore of computers there was special excitement. For, after only two years of corporate life, this upstart of the business had already—

- established itself as the third-ranking digital computer firm—with over 17 installations
- built up its contract computing center into the largest in the West
- developed a specialist data processing sales force in eight key cities
- started construction of still another new plant to double output

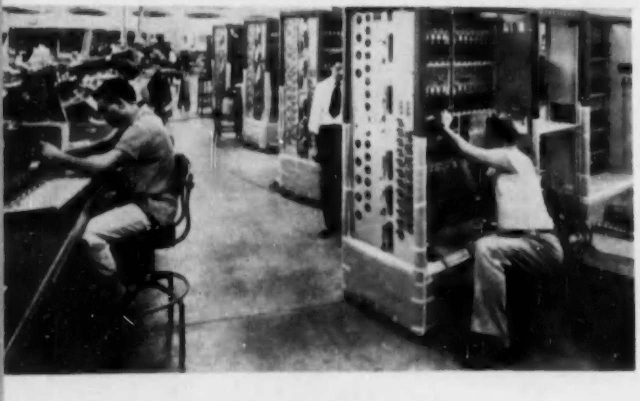
ElectroData began in the Computer Div. of Consolidated Electrodynamics Corp. and spun off as an affiliate in October 1953. The young engineers who started it were superb designers with an uncanny grasp of the commercial prospects for a medium-priced general-purpose computer with some selected large-price capabilities. Their early production goal was one system

DESIGN has been simplified by some neat printed circuitry—so says engineer Walt Costello to Neal Worthy.



TESTING the 40,800-digit magnetic drum memory are engineers Larry Bowley, Bob Chartrand, and Jack Sorosky.

PRODUCTION of computers is now done on a line-flow basis in the long, air-conditioned, sound-proof plant area.



INSTALLED at Magnolia Petroleum Lab in Dallas is this handsome unit, with Research Physicist O. D. Ferris at the console.

ON NEW YEAR'S DAY ALL EYES WERE ON THE TAPE . . .
The predictions that reeled off certainly impressed the press (see below).

per month and an average price of $125,000; these first few units were immediately corralled by military research facilities. Gradually, commercial value of the pioneer installations was recognized: two oil companies bought, then Allstate Insurance Co.; recently, Babcock & Wilcox installed a unit for research on its equipment.

Today, in the new brick plant, production is reckoned at three systems per month at an average sale price of $200,000, and there is an order backlog for twelve systems. Because of the growing load, ground has already been broken for an adjacent plant of 40,000 sq ft, which will more than double production capacity.

Why this phenomenal growth of ElectroData? Certainly one big reason has been topnotch engineering and good timing. But the results also hint at uncommonly adept people at the business helm. The young company will accept its very first profits this coming year—although it surely could have cut corners for a return before this. Further, recognizing the dearth of people able to run its machine, it spent money to set up an excellent training school almost at the start. Some believe that this has pushed purchases ahead by as much as a year. And finally, the company has shown a flare for promotion. Hardly a week has gone by without the press knowing where the latest ElectroData effort was aimed. Or who had just joined the crew at Pasadena.

A typically neat example of the company's promotional verve hit the nation's press the day before New Year's, when its computer center came out with pre-calculated scores for all Bowl games. Results of contests bore out Datatron's predictions to within a few points. Sportswriters, however, were quick to sense a challenge to their traditional crystal-ball function and a critical din of sorts (much to ElectroData's delight) dotted the sports sections in early January. . . .

THE POWERHOUSE
By JIMMY POWERS

There was quite a stew over the attempted use of an electronic "brain" in Los Angeles to predict winners of five major bowl contests. It was stated with a certain air of deep confidence and smug superiority that "this was the first time a computer has been used to analyse data involved in sports events."

The picks by the Electrodata Corporation's "Datatron" received a tremendous amount of advance publicity but, in the wake of the actual results, I can't seem to find any notice of what went wrong. The machine assayed weights of linemen and backs, percentage of completed passes, yards-gained-per-try, comparative scores, average distance of punts, and points after touchdown. This, and much more statistical data, was fed the machine.

It came up with Michigan State by 8 over UCLA. Michigan State won by only 3, which means the bettor lost his money. The machine had Mississippi by 4 over TCU. Again a loss, because Mississippi won by 1. Oklahoma, via the vacuum tubes and the Frankenstein computation, was 28 over Maryland. Oklahoma won by 14. Georgia Tech was 6 over Pitt on the Datatron. It won by 7, a creditable showing, indeed.

The machine predicted a tie between Auburn and Vanderbilt in the Gator bowl. Vandy upset Auburn by a plus-12 margin.

I hate to think of what would happen to us all in this stepped up, jet-propelled rat-race if the electronic "brain" had called the Bowl winners 100%.

It is conceivable that millions, deprived of their hobbies, would blow gaskets and go stark, raving mad. There would be no need to run a horse race. The electric brain would have already picked the winner. No need for a political race. The steel-geared brain would give us the governor, the mayor, the new president complete with neatly tabulated returns from all outlying precincts. No need for a U. S. Open golf championship, a Davis Cup or a sailing regatta. All the pertinent factors would be fed into the maw of the robot. No one would have the audacity to question it anymore than the biggest corporations or banks challenge the higher mathematics of their block-long IBM automaton.

There could come a day when, with proper allowances for reflexes, wind direction, drift, precipitation, barometric pressure, arm and leg strength, cardio-respiratory factors and IQs, a machine could come terrifyingly close to giving us most sports results in advance. All you have to do is read a simple article in any science magazine on the performance of Nikki rockets, robot planes and the direction-finding of artillery by radar.

Happier When You Don't Foresee Calamity

How many times, with your heart full of hope, have you stepped out onto the first tee on a sunny Spring day with the squirrels frisking amid the dogwood blossoms, the trout leaping in the brook, birdsong filling the woods along the rough? This, you say to yourself, is the day your swing feels right. It is good to be alive. This is the day a reasonable percentage of your putts are going to roll true to the cup. Off you go, your step light, your spirit high.

Until disaster overtakes you in a cavernous trap on the 17th, you were in the clouds. For two hours you were in a golfer's paradise of lucky bounces, good lies and incredible ricochets off rocks and tree trunks. You wouldn't trade those two hours for anything else in the beautiful sun-steeped world.

But, with the electronic brain, you march out on the tee, feed it a succession of punched past scorecards, thrust an arm into a prepared slot for a quick taking of the pulse, blood pressure and skin temperature. More cards are fed into the chromium-plated instrument (No good club in 2,000 AD would be without one). Gears mesh, lights flash, and—before you have taken a single Mulligan, or practice swing, out comes your completed 18-hole total. There it is. No debate, any more than you would argue with your office comptometer. There are your pars, bogies and that wonderful birdie on the 15th. But there alas—law of averages—is that nightmarish 11 on the 17th!

Silly, eh? Well, 20 years ago, who'd have thought you'd drive a car and shift gears punching buttons like doorbells?

. . . ESPECIALLY SPORTS EDITOR JIMMY POWERS
whose New York Daily News column berated, then execrated the computer

STILL MORE IN THE DIGITAL ROUND-UP

Diverse Uses for the DTs

It used to be that digits were simply something you counted on. But—as the Datatron sports predictions above indicate—it isn't necessary nowadays to count on anything—the DTs (digital techniques) will do it for you. In just the past month these new applications for DTs have infiltrated our culture and commerce:

▶ M. Low & Co. has come out with an electronic computer for nautical chaps. Feed it starting longitude and latitude, and speed over the bottom, and it will predict your position at any time. The unit wowed them at the recent New York boat show.

▶ Bonneville Power Administration, Portland, Ore., now uses a Bendix computer to relate stream flow and reservoir storage in the huge system to associated power generation and transmission operations.

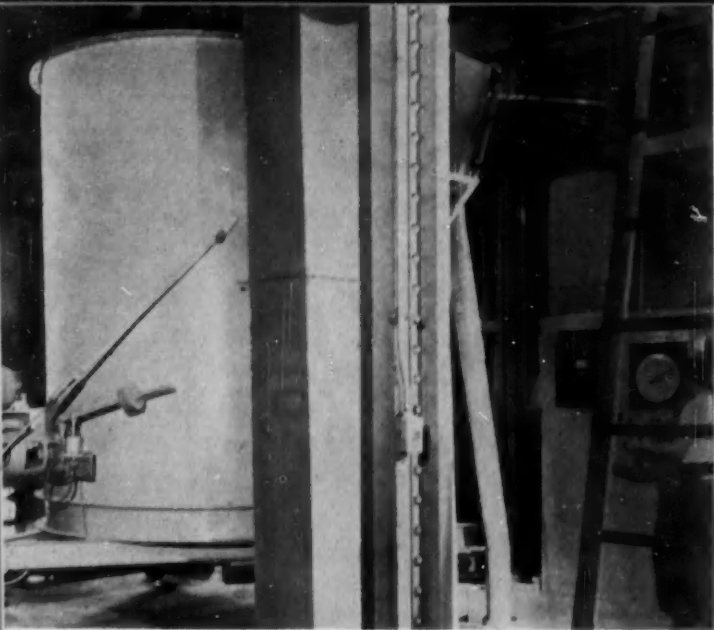
▶ how do they get those weird names for drugs (like sulfadenial)? They do it with a computer, that's how. Chas. Pfizer & Co. has revealed that it selects names for its new medicines from an IBM 702 computed list of 42,000 words that embrace all the dramatically unpronounceables possible. Some unused samples: cliohacyn, platuphyl, ywuvite. Wonder if they list digititus?

Magnetics Sub for Tubes

Scheduled for early appearance in 1957 is a new Remington Rand computer that will use magnetic amplifiers instead of tubes and sell in the $12,500 range. Professor Presper Eckert, co-inventor of the Univac and inventor of the "Ferractor" amplifiers, claims the computer will perform accurately at from minus 60 to plus 220 deg F and will be much simpler in operation than equivalent units today.

MIT Plans Computing Center

An important addition to the $4 million Karl Taylor Compton Laboratories now under construction at MIT will be "the largest and most versatile data processing center yet to be made available for education and basic research". It will be staffed by more than 30 people under the direction of Dr. Phillip M. Morse, Professor of Physics. The principal tool at Tech's center will be an IBM Type 704 to be installed by IBM, which will also contribute to the cost of maintenance and operation.



Strain Gage Hefting Solves a Big Solution

Pictured is a simple but very effective way to control the make-up of solutions in large batches. The 10,000-gal tank is supported on an I-beam triangle, each corner of which rests on a Baldwin SR-4 load cell. Outputs from the three cells are transmitted to the electronic indicator, on the panel, which totals and directly reads the weight of tank contents in pounds. The gages respond to changes of less than 10 lb in 30,000-lb batches and repeatability is within 0.1 per cent. The installation shown—a sugar-to-water make-up operation—is in the Betteravia, Calif., plant of the Union Sugar Div. of Consolidated Foods Corp. The weight indicator is equipped with set-point contacts that actuate the automatic valve on the sugar and water flow lines, visible atop the tank.

CONTROL CONCLAVES

Princeton, Dec. 29-30

Neither nostalgia over Christmas turkey, nor anticipation of New Year's ham seemed to distract the 200 engineers at this ACS Industrial and Engineering Chemistry Div. Symposium on Transient Chemical Process Behavior and Control. The studious group—mainly chemical engineers out to assay the impact of dynamic analysis on their field, and the advance-guard process control regulars from ISA and ASME—was there for one thing: to hear a program that covered the influence of process, measuring elements, transmission links, controllers, and actuator dynamics on the design of automatic processes.

The program covered its scope well. It started with a sermon by CtE's Bill Vannah, who stressed the importance of cross-fertilization between the designers of processes and the designers of control systems. Bill injected an interesting note by likening this pioneer meeting on dynamic analysis to start-of-the-century Freudian conclaves that revealed the budding science of psychoanalysis. The solid material that followed covered:

▶ control dynamics of heat exchangers —papers by W. C. Cohen and E. F. Johnson, Princeton; J. M. Mozley, du Pont; Sidney Lees, MIT, and J. O. Hougen, Rensselaer; L. M. Zoss, N. W. Golling, and R. I. Edelman, Taylor Instrument Cos.

▶ control dynamics of distillation—papers by T. J. Williams, USAF Institute of Technology; R. F. Jackson and R. L. Pigford, University of Delaware; D. E. Berger and G. R. Short, Phillips Petroleum Co.; and A. Savitsky, E. H. Woodhull, and A. P. Weber, The Perkin-Elmer Corp. The latter group of papers stressed practical methods for determining the right location for analysis instrument sampling elements.

▶ control dynamics of liquid flow—a paper by A. R. Catheron and B. D. Hainsworth, The Foxboro Co.

▶ dynamics of controllers—a paper by J. O. Hougen and Sidney Lees.

▶ mathematical tools for systems analysis—papers by N. H. Ceaglske, University of Minnesota; R. G. Franks and C. W. Worley, Minneapolis-Honeywell Regulator Co., Industrial Div.; and the paper on heat exchange presented by Mozley of du Pont.

▶ methods of determining dynamics by test—the impulse method, covered in the Lees-Hougen paper, and the frequency response methods described in many other papers.

Fine as the material was, there was a noticeable gap: not enough examples of completely flexible systems strategy —i.e., considering the physical arrangement and design of the processing unit as adjustable as the measuring elements, controllers, and actuators. Only the paper on an automatic air heater by the trio from Taylor took this approach. In it the authors demonstrated how the process design could have been changed to improve the dynamic performance of the complete system. Prompted by our reporter's comment on the limitations imposed on system performance when the process is viewed as a "sacred cow" to be harnessed by controls, Bruce Powell, California Research Corp., advised that his organization does indeed design fractionation columns for controllability by considering the effects of column diameter, plate/holdup and vapor flow rates on dynamics.

New Haven, Dec. 27-28

Another CtE editor forsook the holiday hearth to journey to student-deserted halls and explore another pioneer facet of control. This time the site was Yale, where the first organized assault on the implications of "automation" by anthropologists was taking place. The sponsor was the Society for Applied Anthropology and its avowed purpose was "to bring together a group of outstanding scholars and practitioners who will define and discuss the human problems of accelerated technical change".

Our man reports that this meeting was quite different from the "many past soirees on this subject. This one was disarmingly practical—and it grew on you." The anthropologist's approach to automation is through case studies of individual plant situations. His interest is in the reactions of the men (and women) themselves. Hence, two extensive case studies covered the *effect on individuals* of control systems installed in a steel mill and in a power plant. Other papers dealt with the effect of computers on office personnel. All met with keen audience questions and analytical appraisal by a round-table of the speakers at the end of the sessions.

During the talks some unexpected facts dropped like plums into our man's notebook:

▶ automation may not necessarily

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mean more maintenance jobs—the steel mill required only 28 post-automation maintenance men as opposed to the 78 previously on hand

▶ control systems in the steel mills were found to substitute tension and mental fatigue for the worker's simple physical fatigue (but this was probably mainly due to lack of measuring and feedback techniques at these installations)

▶ while the workers generally enjoyed their new "automated" jobs, they had feelings of insecurity due to less rungs on the promotion ladder

▶ the workers are finding automation encourages unpopular shift-type production—expensive automated machinery must be kept in constant operation. Some observers predict shift operations for white collar jobs, too.

Far more than any other conference we have noted, this Yale conclave pinpointed the human values of our technology and drew some startling pictures of problems that can only grow more urgent with time. There was one tremendous shortcoming of the symposium, however: there were no control design engineers on hand to give a few insights into the thought behind their work, or to outline the possible technical repercussions that this work is bound to stir up. Control design men could have enlightened their listeners about other repercussions, too—the human ones—and in this respect the symposium would probably have provided them with their very first opportunity to air their views.

CONCLAVES TO COME

Princeton, March 26-28

Still another pioneer meeting for control engineers will be the Second Annual ASME and AIEE Conference on Automatic Control, co-sponsored by the IRD Div. and the Feedback Control Systems Committee of the two societies, respectively. This in itself makes it important. But the meeting's theme gives it special distinction: the Problem of Nonlinearity in Control.

Looking at the program, it is apparent that just about every top authority on nonlinear behavior will be on hand. The meeting starts with a basic paper on nonlinear phenomena by Ludeke, University of Cincinnati, continues with an historical resumé of the development of nonlinear technology by T. J. Higgins, and then goes into 27 papers. Some samples:

▶ Nonlinear Analog Study of a High Pressure Servomechanism, Shearer, MIT.

▶ Basic Methods for Nonlinear Control System Analysis, Stout, Schlumberger Instrument Co.

▶ Optimum Nonlinear Control, Oldenburger, Woodward Governor Co.

▶ How to Obtain Describing Functions for Nonlinear Feedback Systems, Klotter, Stanford.

Recognizing the significance of the conference and its subject, CONTROL ENGINEERING is now in the midst of a trio of articles on nonlinearity in control (see page 82 in this issue, and page 55 in the February issue). Aimed at a tutorial level, we hope it has encouraged many of our readers to plan to take in this important Princeton conference.

Newark, April 3

CONTROL ENGINEERING, which usually confines itself to reports on national meetings in the field, feels that this forthcoming Annual Symposium by the Newark, N. J. section of ISA rates a special mention. This year the subject is Automatic Data Handling in the Process Industries and consists of six papers that cover the management view, the details of specification, the client-contractor relationship, an engineering case study, an over-all philosophy for data handling, and a report from Canada on an advanced installation. Besides the excellent organization of these topics, the program has this highly commendable aspect: all the speakers are users of equipment. But it took a vender—Bill Archibald of Energy Control Co.—to line up the doings.

Dayton, May 14-16

This year the Eighth Annual National Conference on Aeronautical Electronics will feature several "how-to-do-it" type of papers that should be of especial interest to control engineers. The conference is sponsored by the Dayton chapter of IRE in conjunction with that society's Professional Group on Aeronautical and Navigational Electronics. It will be held at Dayton's Biltmore Hotel. Write for more information to P. O. Box 621, Far Hills Branch, Dayton 9, Ohio.

WHAT'S NEW

U.S. Engineers Impressed by Soviet "Automation"

But Pravda Is Less Charitable

In its January issue, page 36, CONTROL ENGINEERING described the blasé reaction of two visiting Russian control engineers to U.S. "automation". Shortly thereafter three American executive engineers* made the exchange visit to the U.S.S.R. for a tour of its "automated" facilities. The newspaper reports that trickled in from Moscow news bureaus indicated a totally different reaction by the American visitors to what they saw. By and large, they were quite impressed.

A Computer Controversy

One thing that struck the visitors was the huge 100-ft-long digital computer in the Institute for Precision Mechanics and Calculating Technology in Moscow. The unit was reported "as being able to translate languages, as using a photoprinter that records 200 numbers a second, and as containing special tubes in its memory which are capable of executing 1,023 numbers or commands related to any one problem".

Two days after this report, IBM dashed out a "pooh-poohing" release for local editors. "American computer experts were amazed," it said, ". . . (that) the newest Russian 'electronic brain' was considered as being comparable in speed to the best computers in the U.S." Reportedly, said the IBM release, the Soviet unit calculates at the rate of about 7,000 to 8,000 operations per sec. Even "veteran" 701's, it said, can perform 14,000 calculations per sec, the new 704 will handle 30,000 per sec, and the year-old NORC averages around 60,000.

A CONTROL ENGINEERING editor visited Dr. Hall in Detroit to get more specifics on what had impressed him—particularly in those phases of Soviet "automation" that embrace measurement and feedback principles. Some of his comments:

▶ on theory: "The Russians are fully as far along as we are in this country—and with their aggressive determination should catch up to us in practice in a few years." He cited the field of nonlinear control as an area well covered in U.S.S.R.

▶ on machine control: "Contour following systems are well developed, with electrical and hydraulic pick-offs very similar to ours. They use approximately the same hydraulic pressures as we do."

▶ more on computers: Hall was impressed with computer design, circuitry, and layout. One outstanding feature he mentioned was a printout device, consisting of 35 mm tape, which handled 900 numbers per min—including the correct math symbol and decimal point location. The tape is blown up 3½ times for easy reading and as a permanent record. The men running the computers seem highly qualified.

▶ on control equipment: he considered the instruments and electrical packaging "very good, in fact excellent". He also saw some excellent examples of nonlinear damping.

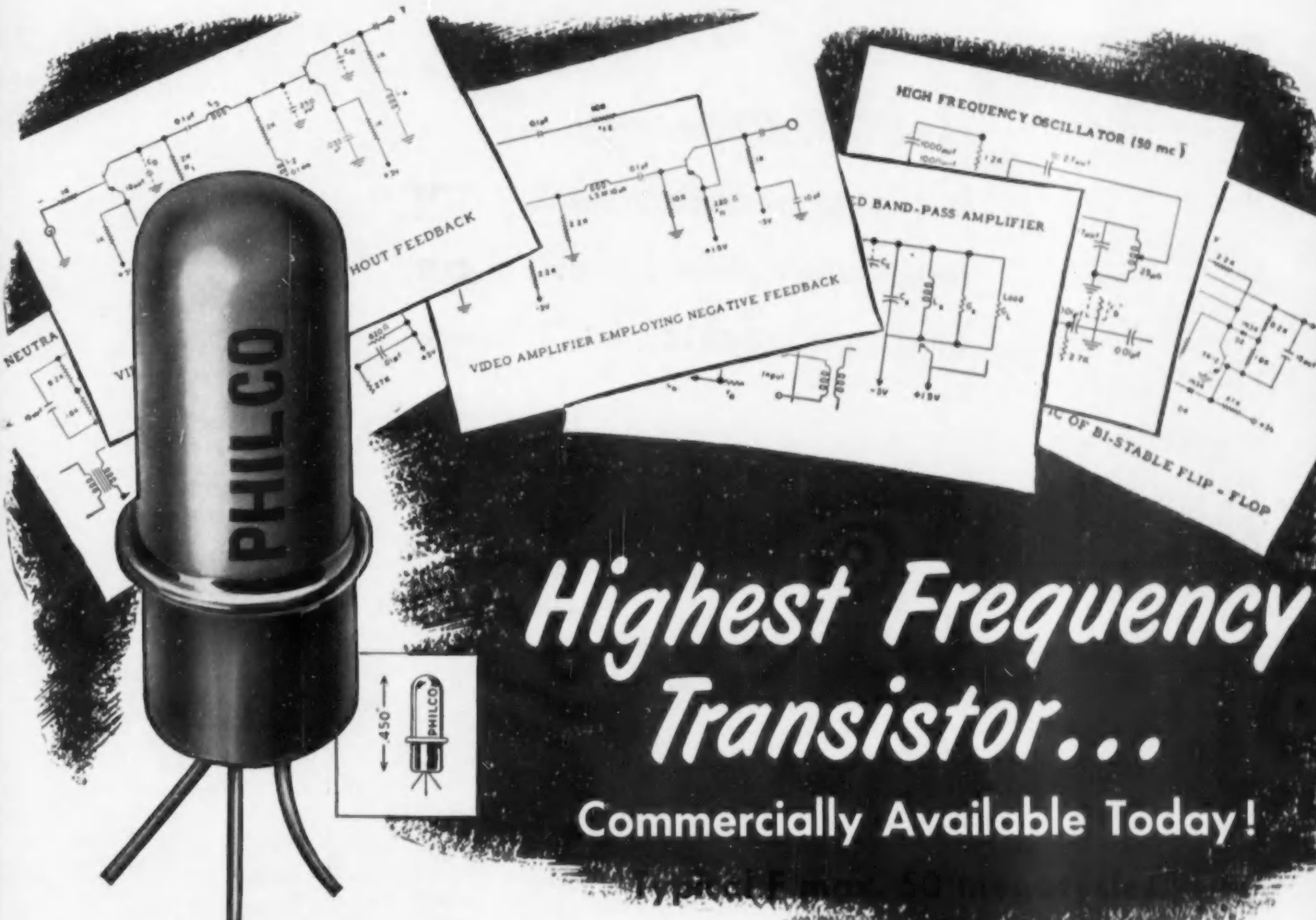
Dr. Hall was particularly impressed with the enthusiasm of the workers and the generous incentive and bonus systems that spur them on. Apparently, plant workers are assigned patents and royalties for new methods and improvements they can claim responsibility for.

Feedback from Pravda

The Russians themselves may not take as charitable view of their own progress in the control field. On Dec. 15—during the actual visit of the American trio—*Pravda* came out with a scathing editorial that accused the Ministry of Machinery and Instruments of failing to make enough instruments and controls for Soviet industry and research.

"The Ministry," said *Pravda*, "clearly underestimates the need for making the instruments and automatic apparatus which are the basis for the introduction of automation. It doesn't manufacture a number of instruments and regulators necessary

* A. C. Hall, Research Director, Bendix Corp., Dr. W. Brandt, Engineering Manager, Westinghouse Corp., and N. L. Bean, Automatic Transmission Div. of Ford Motor Co.



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"We visited one of the design bureaus where electronic computers are being developed. Real enthusiasts are determining the technological levels of the future work there.

"But under what conditions they work! They have small, uncomfortable quarters in which it is difficult to turn around, poorly-equipped laboratories, and inadequate supplies of necessary materials. There are insufficient funds and personnel to develop a number of major projects."

Wind from the Sails

We'll never cease to marvel at the Russians. Just as they were extending themselves to impress American visitors with a carefully set-up "automation" tour, their own *Pravda* knocked the wind from their sails with its biting criticism. And the source of the criticism could well have been those recent visitors to America whose tour of our facilities, though "desultory", apparently gave them many things to think about.

Ramo-Wooldridge Producing 3-Volume Control Handbook

Now in the works under the triple editorship of Simon Ramo, Dean Wooldridge, and Gene Grabbe, is a three-volume handbook on *Automation, Computation and Control*. Volume 1 will deal with *Mathematics and Feedback Control*; Volume 2 with *Computation and Data Processing*; Volume 3 with *Control Systems and Components*. Leading authorities in each of these areas are contributing to the project. It will be published by John Wiley & Sons, Inc.

Gene Grabbe has forwarded CONTROL ENGINEERING a breakdown of

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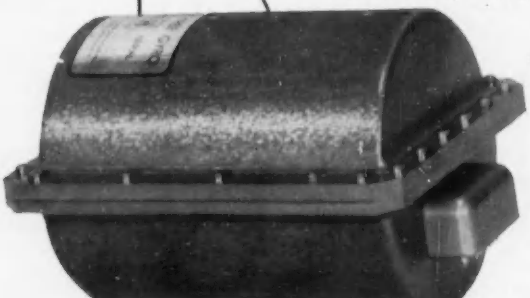
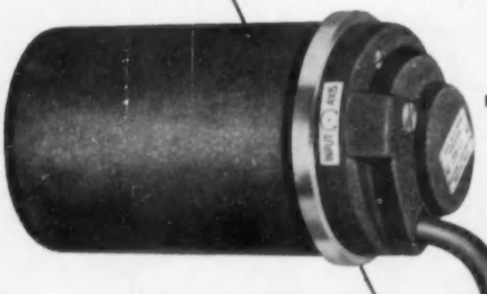


Cageable Free Gyroscopes, Type CFG-P (Potentiometer Pickoff) and **Type CFG-S** (Synchro Pickoff) for guided missile instrumentation and control systems. These gyros measure angular deflection about either one or both gimbal axes. The rugged simplicity of the caging mechanism and the rail-type mounting enable these gyros to withstand severe shock and vibration. Weight — 5⅛ lbs. Size — 5 19/32" long x 4⅜" diameter (exclusive of mounting flange). Drift—less than ¼° per minute. Remote caging and uncaging. ***Write for Bulletin CFG-34.***



Rate Measuring Gyroscopes, Type K for guided missile control and homing systems and flight evaluation of military aircraft. These models measure absolute angular rates where high accuracy and superior dynamic response are essential. Linear output signal proportional to input rate within 0.25% of full scale. Withstand 100G shock in any plane and 15G vibration up to 2000 cps. Weight—3⅝ lbs. Size—5¾" long x 3.20" diameter. ***Write for Bulletin KG-34.***

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Rate Measuring Gyroscopes, Type JR for tactical weapon systems requiring less than one minute warmup. Incorporate damping compensator for constant damping ratio without heater. Linear output signal proportional to input rate within 0.25%. Withstand 50G shock, 15G vibration up to 2000 cps. Angular Momentum — 10^6 gm.-cm.^{2}/sec. Size 3⅜" long x 2.0" diameter. ***Write for Bulletin JG-34***

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specific topics that will be covered in each of the handbook volumes—and they are impressive. Volume 1, for example, will include Information Theory, Smoothing and Filtering, and Data Transmission. Volume 2 will cover analog computers and analog-digital hybrids. And Volume 3 will deal with such complex systems as navigation fire control, and nuclear and digital control of machines. The study will also close in on advanced hardware, including gyros, continuous analyzers, magnetic amplifiers, and semiconductors.

Important Moves by Key People

▶ When Hydro-Aire, Inc., came over to National Aircraft Corp. as a division, a bonus for NAC went along in the deal. The bonus: **Dr. Hans E. Hollmann,** Hydro-Aire's research scientist. Now NAC has appointed Hollmann director of research for its Marvelco Electronics Div., which will set about adding personnel for research into advanced techniques and circuitry in the application of transistors and other semiconductors. Hollmann inaugurated Germany's microwave program more than 25 years ago, when he developed the first microwave link. In 1936 he published the first encyclopedia on microwaves, the only forerunner of MIT's radiation series, and in 1947 fled to the U. S. under government sponsorship. From that year until he joined Hydro-Aire in 1954, Hollmann conducted the one-man research science department at the Naval Air Missile Test Center in Point Mugu, Calif. He's author of more than 100 technical papers and holder of more than 300 patents.

▶ **Asa H. Myles'** appointment as chief engineer of Electric Controller & Mfg. Co. comes hard on EC&M's incorporation into the Square D Co. as a division. Myles, who also joins his company's operating committee, has been with EC&M since 1930. He was named assistant chief in 1943.

▶ Fairchild Camera & Instrument Corp. has brought in **Milton A. Chaffee** to steer an electronics and systems research program designed to spur production of electronic defense and commercial products. Chaffee, formerly director of systems at the Air Force Research Center, Cambridge, Mass., was the man who installed the radar system for the Berlin airlift. During World War II he did radiation work at MIT and in Malverne, England, Caserta, Italy, and Paris; during the Korean war he was chief civilian scientist for the Far Eastern Air Force; and between wars he was supervisor of field service for Airborne Instrument Laboratories and development planning officer and a specialist on tactical warfare for the Air Force.

▶ **Henry W. Patton,** Airpax Products


A. H. Myles


M. A. Chaffee


H. W. Patton


K. F. Oldenburg


P. G. Yeannakis


F. S. Ward

Co.'s new Engineering Dept. project leader, is a noted speaker and an inventor (he holds 15 patents). His talk at the IRE National Convention this year, on application of magnetic amplifiers to industrial controls, will be his second before that body; he'll also address the AIEE winter general meeting in New York City. Before joining Airpax, Patton was with Collins Radio Co. and The Baldwin Piano Co.

► Two new assistant chief engineers head up Clary Corp.'s development programs in electronic and data-processing equipment and in business machines. They are: **Kenneth F. Oldenburg,** who remains in charge of the data-processing laboratory, and **Milton Scozzafava,** who continues to direct the Business Machine Dept. Scozzafava did some of the work on the first Clary adding machine in 1946. Both men will report to Chief Engineer **Robert E. Boyden.**

► Principals in a series of appointments by Infra Electronics Corp. are: **P. G. Yeannakis,** who will take charge of all production facilities; **Clint Honneywell,** who will direct development of production engineering methods; and **Samuel C. Lapidge,** who will steer the Engineering Dept.'s synchro development group. Yeannakis and Lapidge were with Bendix Aviation, Honneywell with Servo-Tek Products Co.

► Taylor Instrument Co.'s general sales manager, **Frank S. Ward,** has been elected a director of the company and a member of its executive committee. Other new members of the committee are **Marc E. Porter,** assistant treasurer, and **Karl H. Hubbard,** technical director.

► **W. V. Neisius** fills the top post in J. B. Rea Co.'s new Computing Applications Dept. Neisius, as director, will oversee his department's work in analyzing and studying the application of a large variety of problems to Rea's Readix computer. He was on the mathematics faculty of Georgia Tech for 10 years.

► Fansteel Metallurgical Corp. has merged several design, development, and laboratory engineering functions into a Centralized Engineering Dept. and has put **Ralph W. Rawson** at its helm. Rawson, who joins the company as chief engineer, was director of industrial planning for the Bureau of Aeronautics at Wright-Patterson AFB, Dayton, Ohio.

► When **Robert L. Morgan** stepped up to vice-president for engineering of


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WHAT'S NEW

Neely Enterprises, **Robert H. Brunner** succeeded him as sales manager. Morgan joined Neely shortly after World War II, Brunner in 1952.

▶ **William G. Newton** will supervise industrial and methods engineering for the Beckman Div. of Beckman Instruments, Inc., as the division's new chief industrial engineer. He was with General Aniline & Film Corp.

▶ In charge of the new Contracts Div. of American Bosch Arma Corp.'s Arma Div., as its vice-president, is **John J. Giba,** formerly assistant chief engineer. He joined Arma in 1932, taking over the Project Engineering Dept. in 1946. His division consolidates the company's business office and Sales Div.

▶ **Arthur L. Wade** has been named manager of Bailey Meter Co.'s Patent Dept.

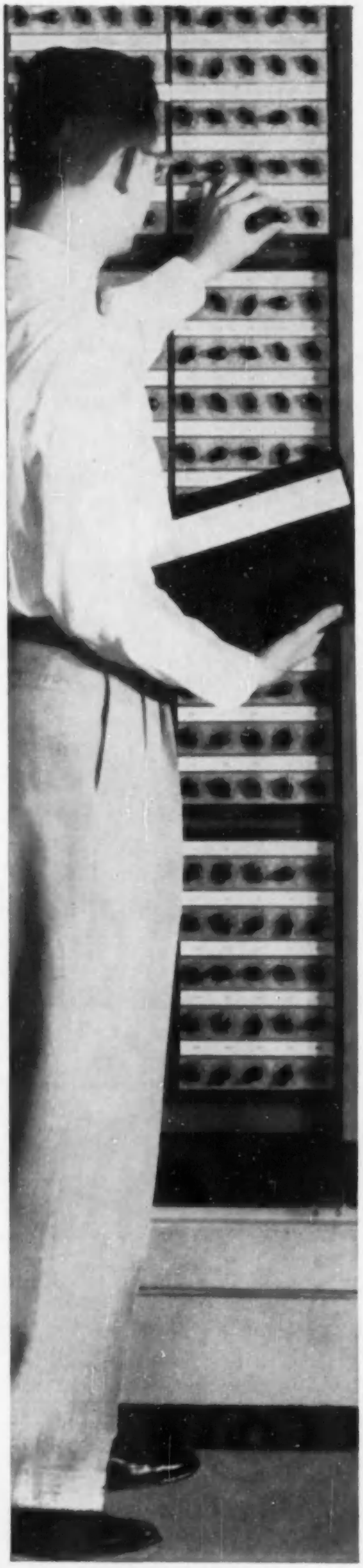
▶ Link Aviation, Inc., has created a new position, director of advanced planning, and filled it with **George Friedl, Jr.,** formerly vice-president for manufacturing. Other Link appointments: **William W. Wood, Jr.,** formerly vice-president for engineering, to V-P for manufacturing; **John M. Hunt,** formerly head of the Research and Development Depts., to manager of the Engineering Div.; and **Monson H. Hayes, Jr.,** to director of R&D.

▶ **Dr. Clay L. Perry** has been granted a nine-month leave by the Naval postgraduate school at Monterey, Calif., where he is supervisor of the computer laboratory and professor of mathematics, to take charge of Stanford Research Institute's program in the use of a new computer acquired jointly by SRI and Stanford University.

▶ **Dr. Rudolfo Quarenghi** is returning to Officine Nuovo Reggiane in Reggio Emilia, Italy, to supervise engineering and production of equipment manufactured under a Richardson Scale Co. license. He'll be in charge of weighing, materials handling, and automatic proportioning machinery earmarked for European process industries. His appointment follows a three-month training period at the Richardson plant in Clifton, N. J.

▶ The new general manager of Baird Associates, Inc., **Dr. Bruce H. Billings,** will continue as director of research. He has also been elected a director of the company.

▶ New additions to Consolidated Electrodynamics Corp.'s Systems Div. are **Samuel Gilman,** technical assistant to the director, and **Sidney Hatchl,** project chief. Gilman, who will be



Panalog Information Systems guide management in raising plant output and profit

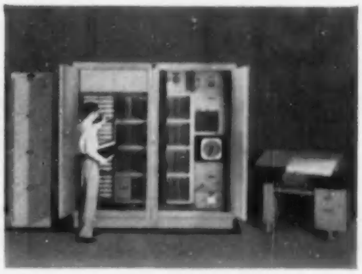
Panalog 605 Information System supplies management control information. Now, operating personnel and management can receive organized digital information on any process, instantly and continuously. Information can be presented in a variety of forms for immediate control action as well as for engineering and accounting analysis. A typical presentation method employs an electric typewriter and patented log chart. Readout can also be made on punched or magnetic tape, punched cards, or can be fed directly to computers.

Periodically logs and continuously scans. A precision servo measuring system quantizes process variables during automatic, periodic logging. A high-speed electronic measuring system detects off-normal conditions during continuous scanning of all variables. Normal and return-to-normal values are printed in black—off-normals in red. A complete log of all variables as well as a summary of off-normals can be made at any time.

Completely flexible and expandable. Panalog components are standardized, packaged modules. The system can be easily expanded or modified in the field. The Panalog 605 is sufficiently flexible to supply digital information for any management requirement.

Write for literature. Literature presenting a comprehensive treatment of the Panalog 605 is available. If you wish, a Panellit representative in your area will be happy to discuss the possibilities that a Panalog Information System offers your company.

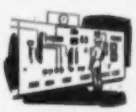
Full scale, adjustable, high and low off-normal limits are provided for each input variable. Basic system capacity, 200 points with one electric typewriter — can be expanded. Accuracy, ±.25% of full scale range. Logging speed, approximately one line per minute. Scanning speed, five points per second, between logs.



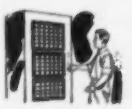
Logged values are grouped by processing unit on chart. Audio-visual alarms accompany detection of off-normals. When scanning, off-normal values are identified and printed in separate chart area. Totalized and averaged values as well as plant efficiencies can be automatically computed and recorded by the system.

U.S. Pat. No. 2,701,748

Engineered Information Systems For Industry



Graphic Panels Control Centers



Panalarm Annunciators

Instrument Services Division

PANELLIT

PANELLIT, INC.

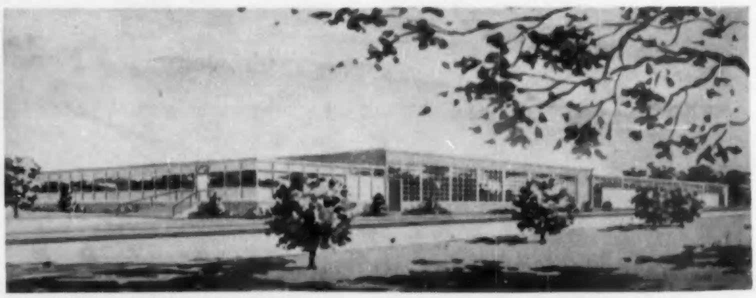
7461 N. Hamlin Ave., Skokie, Ill.
Panellit of Canada Ltd., Toronto 14

special consultant on electronic data-processing systems, has been with Curtiss-Wright Corp., Westinghouse Electric Corp., American Machine & Foundry Co., Boonton Radio Corp., and General Precision Laboratories. Hatchl was with Electro-Technical Laboratories.

▶ Berkeley Div. of Beckman Instruments, Inc., has added **David C. Kalbfell**, president of Kalbfell Electronix and an instructor at San Diego State College, to its battery of consultants.

▶ These men have joined the engineering staff of Gulton Mfg. Corp. (former companies in parentheses): **Leonard Weiss** (Westinghouse Electric Corp., Sabin Metal Corp.); **Joseph E. Sidoti** (Sylvania Electric, Walter Kidde, Freed Radio); and **Walter P. Miller** (Western Electric Co.). Physicists **Daniel S. Schwartz** and **Richard J. Wiack** have joined Glenco Corp. and Vibro-Ceramics Corp., respec-

(1) NEW SPINCO RESEARCH CENTER



(2) COPE DOUBLES OUTPUT

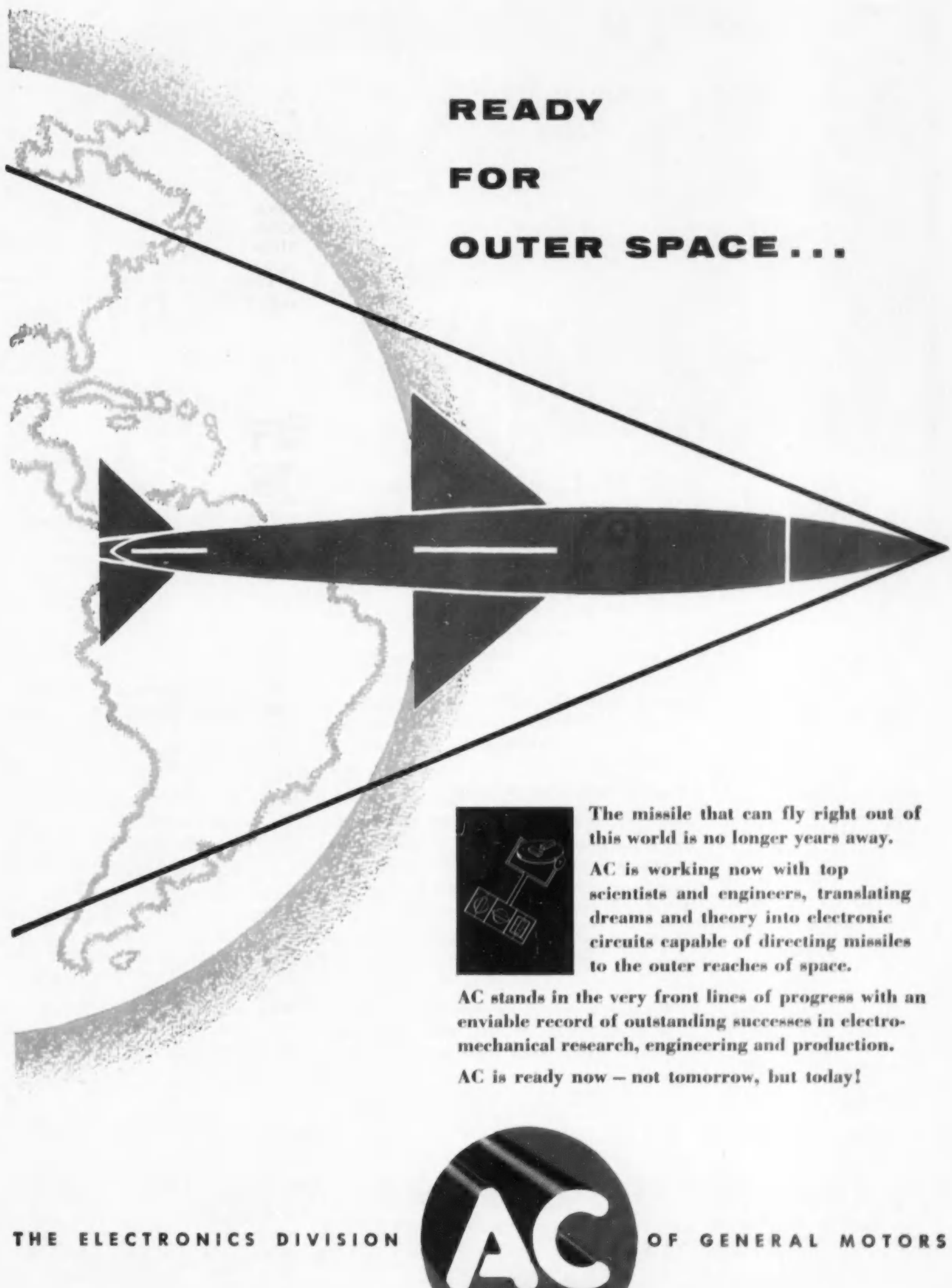
(3) WATERS EXPANDS

DRAWING BOARD VIEWS

(1) SPINCO—This $500,000 medical research and development center in Standard Industrial Park, Calif., will house every department of the Beckman division but manufacturing. Its 30,000 sq ft are designed to expand into 100,000.

(2) T. J. COPE—This new Collegeville, Pa., home for Cope and its Instrof Div. will double production space, and, it's hoped, output. The move from Philadelphia will be made in April.

(3) WATERS MFG.—The company was scheduled to expand into this 10,000-sq-ft building in Wayland, Mass., last month. It's built to "give" for further growth.


READY
FOR
OUTER SPACE...
The missile that can fly right out of this world is no longer years away.
AC is working now with top scientists and engineers, translating dreams and theory into electronic circuits capable of directing missiles to the outer reaches of space.
AC stands in the very front lines of progress with an enviable record of outstanding successes in electro-mechanical research, engineering and production.
AC is ready now — not tomorrow, but today!
THE ELECTRONICS DIVISION
AC
OF GENERAL MOTORS

tively, associated companies of Gulton Industries, Inc.

▶ The National Bureau of Standards has taken on four new staff members and two post-doctoral research associates. The names of the first four and their respective sections are: **Dr. Harmon H. Plumb,** cyrogenic physics laboratory; **William Pearlman,** nucleonic instrumentation; **Lawrence Fleming,** mechanical instruments, Mechanical Div.; and **Seymour Henig,** electronic instrumentation. The two research associates are **Drs. R. J. Prosen** and **Morris Krauss.**

U. S. Unlocks Door to AT&T Patents, Forces IBM to Sell

WASHINGTON, Jan. 25—Yesterday, in what the government called the "largest and one of the most important patent-freeing actions on record", American Telephone & Telegraph Co.'s 8,600 patents went into public domain. Today, the government shook loose IBM's landlord grip on its calculating machines and other electronic devices. Both developments reflect a charitable attitude on the part of the government, but their design was rather poorly expressed as part of "a program to open up the electronics field".

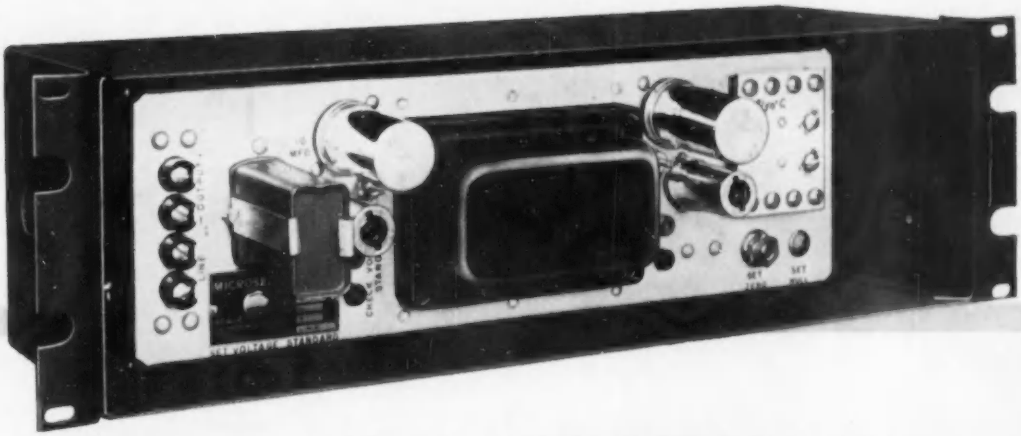
What It Means to AT&T

The settlement of a government anti-trust suit against AT&T means that the company must release patents on such things as the transistor, the solar battery, and its own color television system. It also means that AT&T's Western Electric Co. must sell its subsidiary, Westrix Corp., and that the parent company cannot receive patent royalties from Western Electric in connection with sales to companies in the Bell Telephone system

. . . and to IBM.

The significance of IBM's consent to a similar decree is also manifold: the company no longer can collect, for example, \$35,000 a month on every Type 704 computer that it rented to business and industry. Instead, any firm that can afford the \$1 million-to-\$1½ million price of the computer has the option to buy it outright. The consent covers everything from these giant calculators down to manual punchers, and puts IBM on notice to release for licensing all pertaining patents.

IBM, however, may have forestalled



NEW TRANSMITTING POTENTIOMETER OFFERS 7 BIG FEATURES

- ★ **Extreme sensitivity. Responds to input change of 3 microvolts or less.**
- ★ **Self-contained continuous voltage reference. No standard cells.**
- ★ **No batteries or periodic standardization. Continuous accuracy without drift.**
- ★ **Simple circuitry. Only 2 single triode tubes.**
- ★ **Interchangeable range card. Ranges easily changed in the field.**
- ★ **No slide wires or choppers. Trouble-free operation.**
- ★ **Fast response: 0.04 second time-constant for 1000° F. span.**

The Series 184 Transmitting Potentiometer is the latest addition to the 'American-Microsen' System of Electronic Transmission and Process Control. With this new unit, it is now possible to measure and control thermocouple temperatures or the signals from such devices as pH amplifiers, gas analyzers, resistance thermometer elements, and other electrical systems.

The extreme sensitivity of the new Potentiometer, plus the high resolution and response speed of the 'American-Microsen' Control System, makes it possible to control process temperatures with the high accuracy required by present-day production demands.

The 0.5 to 5.0 ma. signal output can be transmitted 30 miles or more, over a single 2-wire circuit. In addition to 'American-Microsen' receiver, the signal will operate standard d-c milliammeter indicators and recorders.

OPERATING SPECIFICATIONS

Spans: 6 to 50 millivolts d-c.
Suppression: Up to 5 times span.
Output Signal: 0.5 to 5.0 ma. d-c.
Sensitivity: 0.003 millivolts (0.1° F.).
Repeatability: 0.02 millivolts. (0.6° F.).
Input Source Impedance: 200 ohms maximum.
Effective Input Impedance: 1000 ohms per millivolt of span.
Output Load Impedance: 3000 ohms maximum.
Speed of Response: 0.8 seconds for 99% response on 6 millivolt span. Speed increases with span.

Write today for Bulletin MTT810.

MANNING, MAXWELL & MOORE, INC.

MANNING MAXWELL & MOORE INC. M&M TRADE MARK

INDUSTRIAL CONTROLS DIVISION, STRATFORD, CONNECTICUT

MAKERS OF THE 'AMERICAN-MICROSEN' TRANSMISSION AND PROCESS CONTROL SYSTEM, 'AMERICAN-MICROSEN' ELECTRO-PNEUMATIC TRANSDUCERS AND ELECTRO-HYDRAULIC CONTROL VALVE OPERATORS.

an attack by Sperry Rand Corp., which has charged it with trying to sew up the tabulator field. Sperry Rand could have used the government complaint as evidence in its $90 million suit, but IBM's consent puts the complaint out of bounds.

All Around the Business Loop

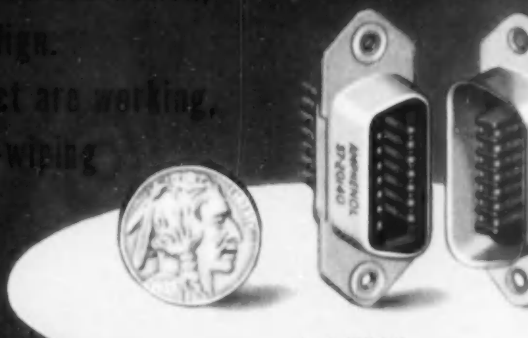
The word in the control industry during the past few weeks seemed to be "acquisition". The word, and the activity that went with it, were reason enough to spray these acquisitions with the top-of-the-news spotlight, ordinarily reserved exclusively for intracompany developments. These too, of course, provided their usual candid glimpses into what's going on in the field, and since just five will be reported this month, it might be well to cover them before going on.

▶ Guided missile fever (see February's *What's New*) continues to spread. One of the latest companies to join the torrent, **Allen B. Du Mont Laboratories, Inc.**, is also one of the biggest. Du Mont plans to channel all design and development work in missiles into its new **Missiles Engineering Dept.**, which for the present will split activities between the main office in Clifton, N. J., and brand new facilities in Los Angeles. Laboratories in both cities have been executing study and design contracts with the Navy's Bureau of Aeronautics and other groups, and consulting on subcontracts for missile builders.

▶ **Leeds & Northrup Co.** will build the entire control system for the 1,000-kw pool-type nuclear reactor designated by the AEC for the University of California. Prime contractor is **Foster Wheeler Corp.** The reactor is scheduled to start operating at **Livermore Research Laboratory**, Livermore, Calif., next December.

▶ When **Philco Corp.** and **Sprague Electric Co.** establish a joint idea file for Philco's surface barrier transistor, there may be more to the results than emergence of another manufacturer of the tiny computer component. Under an agreement licensing Sprague to produce the transistor, the companies will exchange research, development, production, and testing data on every phase of the semiconductor field. Sprague took on the new line just as it tooled up for manufacture of its own germanium fused-junction

Miniaturization
plus increased reliability,
easy, smooth insertion and extraction,
no pins to bend or misalign.
Both sides of the contact are working,
flexing members . . . self-wiping
and self-cleaning.

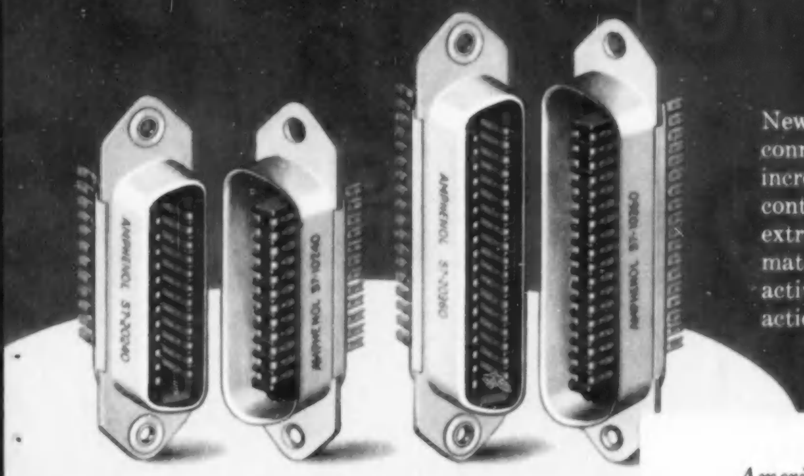


14 CONTACTS

new! Micro-ribbon connectors

AMPHENOL

Micro RIBBON



New Micro-Ribbons are the first miniature connectors to provide reduction in size with increase in reliability. Utilizing an improved 'ribbon' contact, Micro-Ribbons provide easy insertion and extraction even in blind entrance locations. Both mating contacts are self-wiping, self-cleaning, active, flexing members—provide double contact action at all times. Send card for Catalog R2!

24 AND 36 CONTACTS

Micro-Ribbons
illustrated
actual size

American Phenolic Corporation, Chicago 50, Illinois

☐ send me R-2 catalog which includes a complete listing of available MICRO-RIBBON CONNECTORS.

☐ send new Hermetic Seal brochure.

I would like ☐
I am receiving ☐ your periodical "Amphenol Engineering News"

*Name*____________________

*Title*____________________

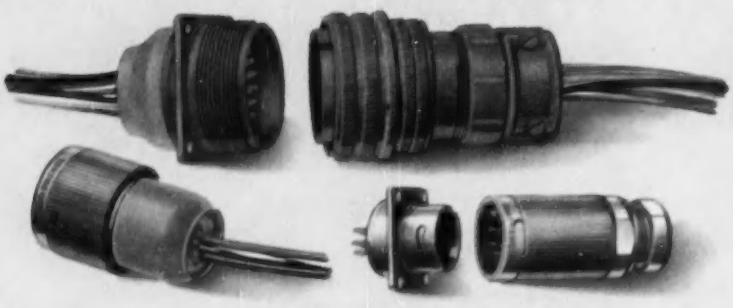
*Company*____________________

*Address*____________________

*City*__________ *State*__________

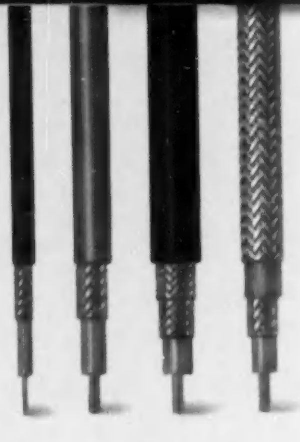
THIS CARD TEARS OUT

AN CONNECTORS



165 SERIES CONNECTORS

AMPHENOL AN connectors are the 'workhorses' of electronics, providing dependable service in literally thousands of applications. From the basic AN design have evolved AN connectors for potting (pioneered by AMPHENOL) and the 165 Series of Miniature AN-type connectors, also available in potting and pressurized constructions. ANs, 165 Series and all AMPHENOL electrical Connectors are listed in Catalog A4.



RF CABLES

Teflon and polyethylene RG-/U coaxial cables, miniature and Aljak cables—send for Catalog W1, a complete and informative catalog and manual, listing all AMPHENOL cables.

AMPHENOL product groups

The AMPHENOL product line is comprised of thousands of electronic components—many are included in the major product groups illustrated. Not described are Cable Assemblies & Harnesses, Sockets, Plugs and the many 'specials' produced by AMPHENOL. General Catalog B4 summarizes the complete AMPHENOL product lines.

American Phenolic Corporation, Chicago 50, Illinois

Amphenol Canada Limited, Toronto 9, Ontario

HERMETIC SEAL PRODUCTS

Brand new Headers join AN-type receptacles in the Hermetic Seal group. All have superior compression seal glass for best hermetic performance. Send for product literature!

RF CONNECTORS

All standard UG-/U types and many special application RF connectors including the new Subminax miniatures bear the AMPHENOL quality imprint. Request RF Catalog D3.

RACK & PANEL CONNECTORS

For rack & panel applications AMPHENOL offers famous Blue Ribbons, miniature and standard pin & socket types and a complete line of Princir (printed circuit) connectors. Designed and manufactured to AMPHENOL standards. Catalog R2.

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CHICAGO, ILL.

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Chicago 50, Illinois

AMFORM 2725-26300

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transistor, which can give efficient performance at frequencies up to three megacycles. It will be on the market this year.

► Two other companies that have put their heads together with a view to-ward a fruitful trade in ideas are **Electric & Musical Industries, Ltd.,** of Middlesex, England, and the **Cincinnati Milling Machine Co.** The intention: an integration of the study and development of electronic machine tool control equipment. Icing the contract are the Cincinnati company's world-wide reputation in milling and copying machines, and the EMI group's name in gunfire control computers, radar and navigation equipment, telemetering, and guided missiles.

► Two computing and data analysis facilities—digital and analog—have been established by **Cook Research Laboratories Div.** of **Cook Electric Co.** Heart of the digital facility is the **IBM** CPC computer, which can add or subtract 2,000 times per sec, and the most important piece of equipment in the analog facility is **Goodyear Aircraft's** GEDA.

The acquisitions:

► A good choice to start off the list is **Norden-Ketay Corp.'s** acquisition of **Gyromechanisms, Inc.,** its assets, business, name, and goodwill—Gyromechanisms will continue to operate at Halesite, Long Island, N. Y., under former President Stokley Webster, who becomes general manager of the **Gyromechanisms Div.** Among the 65 employees involved in the transaction are members of a specialized gyro development staff whose significant projects include a new line of small, fully floated rate gyros, a floated two-axis gyro, and a compensated vertical system for greatly increasing the in-flight accuracy of vertical reference of high-speed aircraft.

► The **Precision Potentiometer Div.** of **Electro Circuits, Inc.,** purchased by **General Controls Co.,** will operate as an independent unit under Bruce Grimm, chief engineer. All divisional personnel are included in the deal.

► Just before its acquisition by **Hunter Mfg. Co., Bristol Engineering Corp.** had been awarded a contract by Edwards AFB for design, fabrication, and installation of what will be the largest thrust and weight measuring stand in the world. The 11-year-old company will continue work on the stand as a subsidiary of Hunter, whose plants in Bristol, Pa., Tucson, Ariz., and Mechanicsville, Md., specialize

in chemical processing of military instruments and ordnance materials and aluminum fabrication. Bristol's field is aircraft structural components and automatic electronic testing equipment.

► The sale of **The Swartwout Co.'s Power Plant Equipment Div.** to **Republic Flow Meters Co.** gives Republic a new division with a ready-made line of desuperheaters, regulating valves, feed water regulators, pump governors, and air operated controls. Swartwout plans to give more time to its other divisions and to drop those steam specialties that did not go with the sale. Among the latter: exhause heads, separators, Airfuges, and feed water heaters.

► **Technology Instrument Corp.'s Instrument Div.** has gone over to **Acton Laboratories, Inc.** This means an Acton trademark for TIC's phase meters, phase standards, z-angle meters, vacuum tube voltmeters, direct-reading recorders, and oscillators and amplifiers.

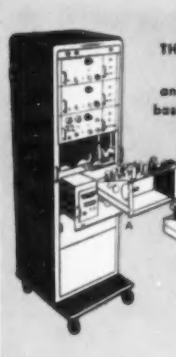
► As a subsidiary of **National Aircraft Corp., Mag-Electric Products, Inc.,** will continue to produce its magnetic amplifiers, power supplies, delay lines, electronic test equipment, and transformers. Among the more than 70 employees retained is President Reagan C. Stunkel, who will be president of the subsidiary. NAC's Vice-president Robert O. Vaughan joins him as V-P.

► With its acquisition of **Tactair, Inc., Aircraft Products Co.** gets a subsidiary that puts it into the field of flight control equipment and instrumentation. The deal also brings to APC William Harcum, who was with **Sperry Corp.** before joining Tactair to take charge of research and development in automatic pilots and related devices. One of his current projects: a new type of automatic pilot for commercial aircraft. Elwood M. Hunt, general manager of APC, becomes president of the new subsidiary.

► Manufacturing facilities of **Autron Engineering, Inc.,** is at the disposal of **Judge & Co.,** engineers, now that the specialist in automatic rubber molding plants and ferrous and non-ferrous foundries is a part of Autron. Judge's principal executive, Royal J. Judge, joins Autron as project engineer.

An upswing in new plants and facilities has also been noted around the business loop. Among these developments:

► An advanced flight and research center for **Sperry Rand Corp.**—Phoe-



THE "150" DESIGN CONCEPT

1. A system starts with an 8-, 6-, 4-, 2- or 1-channel basic assembly which includes a complete recorder assembly, and a Driver Amplifier and Power Supply (A) for each channel.
2. To this basic assembly are added interchangeable plug-in type preamplifiers (B) according to the measurement requirements.

HERE'S REAL oscillographic RECORDING VERSATILITY

DEMONSTRATED AT BOOTHS 455 AND 457 ELECTRONICS AVENUE I.R.E. SHOW

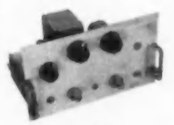
A Sanborn "150 Series" System can be set up to record any of these inputs in any of the channels

AC or DC Signals,

balanced or single-ended, with sensitivity of 1 mv to 2 v/cm (AC), 1 mv to 2 v/mm (DC).

AC-DC Preamp

Logarithmic Level Signals



Audio signals (20 cycles to 20 KC) or DC voltages recorded in logarithmic fashion on 50 decibel chart.

LOG-AUDIO Preamp

Higher Level Signals,

where maximum sensitivity of 1 v/cm, and input impedance of about 200,000 ohms are adequate.

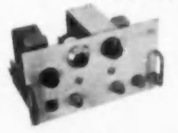
INPUT COUPLING NETWORK

Magnitude and Direction of Physical Variables,

with variable resistance, differential transformer or variable reluctance transducers.

CARRIER Preamp

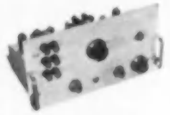
Extremely Low Voltages and Currents,



at sensitivities of 100 μv and 1 μa per cm. (with external shunt of 100 cycles), by means of DC chopper circuit.

LOW LEVEL Preamp

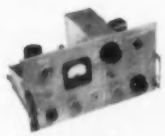
RMS Values of AC Voltages, Currents,



from 25-250 volts, 50 ma — 1 amp.

VOLT/AMMETER Preamp

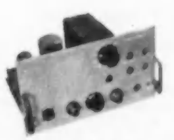
AC Voltage Components



in phase or 180° out of phase with a reference voltage (e.g., servo error signal).

SERVO MONITOR Preamp

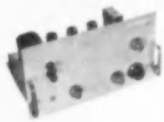
Low Level Signals,



with extreme stability, high gain, and greater bandwidth than with 150-1500 Low Level Preamplifier.

STABILIZED DC Preamp

Symmetric or Asymmetric Wave Form Inputs,



in 350-450 cycles (2 cycles/mm) and 375-425 cycles (1 cycle/mm) ranges.

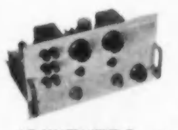
FREQUENCY DEVIATION Preamp

DC Signals

(push-pull, single-ended or difference between two). Basic sensitivity 50 mv/cm to 50 v/cm.

DC COUPLING Preamp

Average Value of AC Watts in a Circuit,



In ranges from 25 volts x 40 ma to 250 volts x 2 amps. (with internal multipliers and shunts which can handle up to 4 amps).

AC WATTMETER Preamp

AND, in addition to this great versatility, *equally valuable* to the user are the basic design features of Sanborn oscillographic recording systems, many of them available *only* in Sanborn equipment. They include inkless recording in true rectangular co-ordinates; improved overall linearity; numerous chart speeds; a choice of vertical mobile-cabinet or portable-case packaging; availability of 2-, 4-, 6- and 8-channel systems especially designed for recording analog computer outputs.

Sanborn engineers will be glad to help you select the equipment best suited to your needs. Contact them with confidence, and ask for a copy of the new and complete "150 Series" catalog.

INTRODUCED AT I.R.E. SHOW

COMPLETE, SELF-CONTAINED EIGHT-CHANNEL SYSTEM ADDED TO 150 SERIES

Model 158-5490 is intended primarily for use with analog computers but capable of other types of recording. Features include 0.1v/cm sensitivity, push-pull or single-ended input, 5 meg. input impedance each input lead to ground. Frequency response is flat to 20 cps, down 2 db at 60 cps for all amplitudes to 4 cm peak to peak.

SANBORN COMPANY, CAMBRIDGE 39, MASSACHUSETTS

WHAT'S NEW

nix, Ariz., additions to the new **Aviation Div.** will speed service to airframe manufacturers in Pacific, southwest, and central states. First on the agenda are a hangar and shop on a 40-acre tract at Sky Harbor Airport, earmarked for work in pilotless aircraft and advanced instruments. Later plans call for construction of a plant and engineering laboratory in greater Phoenix and for development of a former Air Force auxiliary airfield. The plant and laboratory will be started when the hangar and shop have been built, which will be in about a year.

▶ A manufacturing plant for **Baldwin-Lima-Hamilton Corp.** in Waltham, Mass.—Here, next September, a new **Electronics & Instrument Div.** will begin turning out strain gages, load cells, pressure cells, torque pickups, indicating, recording, and controlling instruments, and testing machines. The division will operate in Cambridge until the one-story, 102,000-sq-ft plant is completed.

▶ More space for **IBM**—40,000 sq ft of facilities are shaping up at Oswego, N. Y., where work by portions of the **Military Products Div.** and the **Airborne Computer Laboratories** will get under way later this year. Three main buildings already have been designed. General manager at Oswego is Curt I. Johnson.

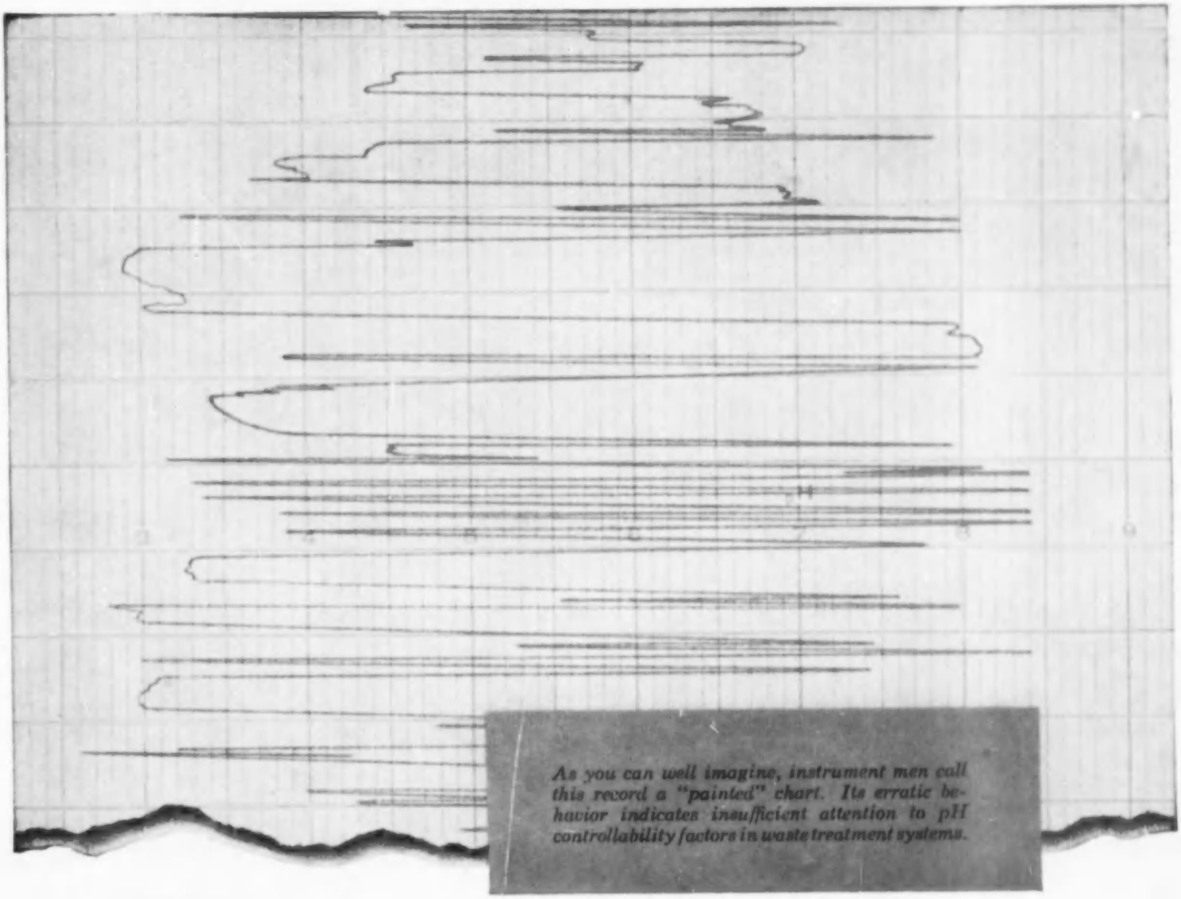
▶ Expansion by **Viking Instruments, Inc.**—Plant and production facilities at East Haddam, Conn., will be doubled to handle increased sales volume and electronic products.

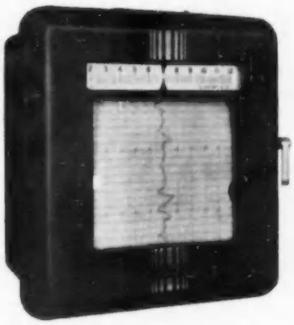
▶ Another for **Rundel Electric Co.**—This San Francisco builder of custom-tailored electric controls is expanding at Millbrae, Calif., where the first sections of a 100,000-sq-ft plant will go into action this April.

▶ Elbow room for **Fenwal, Inc.**—A 100,000-sq-ft addition to this Ashland, Mass. manufacturer's facilities follows close on the heels of a new building that will centralize research in measurement and control of heat and other variables. The new facility will house the **Aviation Products Div.**

In still other news around the loop:

▶ **Kollsman Instrument Corp.** has licensed **Filotecnica Salmoiraghi, S.P.A.**, of Milan, as its exclusive agent in Italy. Initially, the Italian controls manufacturer will represent Kollsman to the Italian government, aircraft builders, and airlines. Later plans, however, call for Salmoiraghi to manufacture Kollsman's line of precision aircraft and optical instruments and systems.





FOR EFFICIENT WASTE TREATMENT

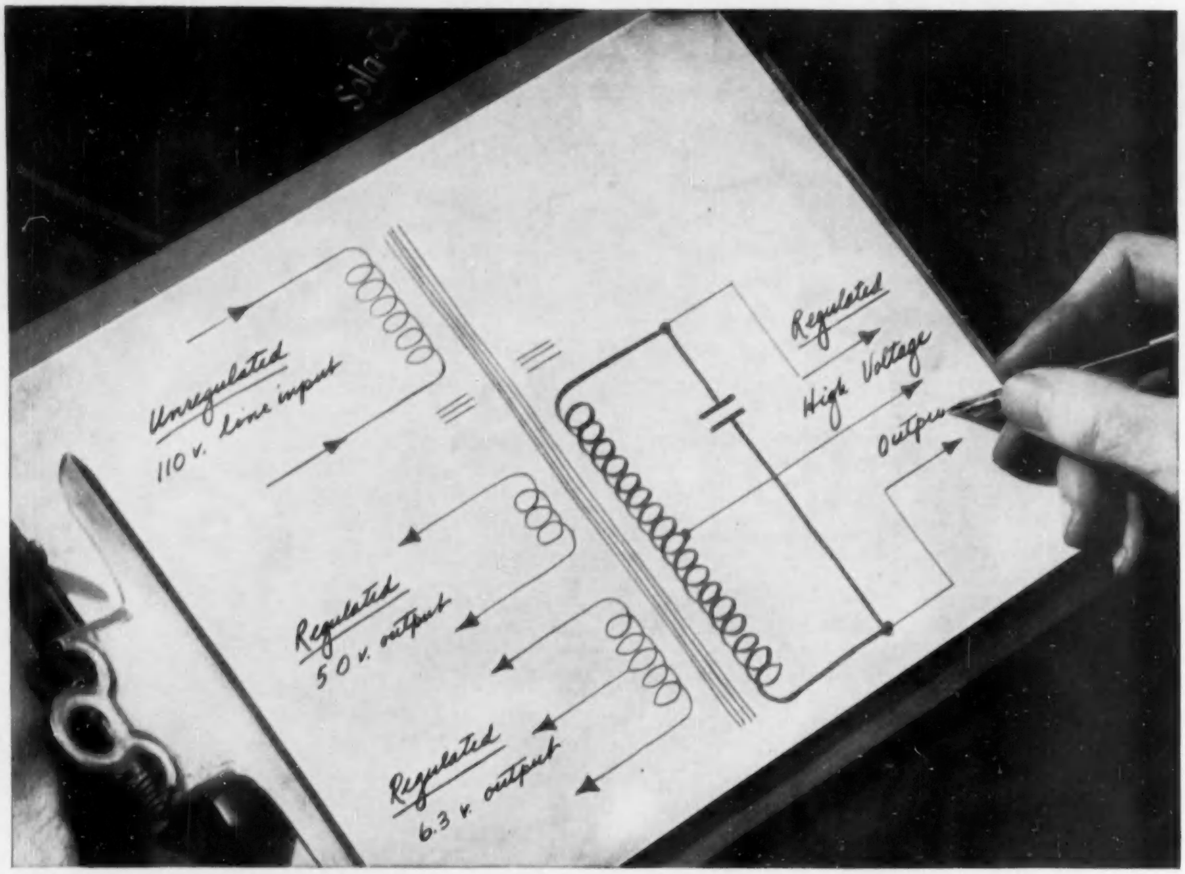
don't "paint" the chart!

In Any Given Waste Treatment System, the factors governing pH controllability—type of waste, variations in flow and concentration, layout and retention of the system, etc.—determine operational success. A painted chart may indicate that a system has been designed and instrumented without due regard to these factors, a regard which only L&N's pH Controllability Analysis provides.

This unique Analysis gives us vital information about the controllability factors of individual waste treatment processes. Our engineers analyze these data to determine the limits within which the process can be controlled in a proposed treating system, or to recommend the physical layout needed to gain the desired degree of control—the answers you need to achieve efficiency in industrial waste treatment.

Process Data Sheet 700(2), "L&N Speedomax Control of Plant Waste Disposal Processes", outlines this approach to industrial waste treatment. Write for a copy and you'll also receive a Controllability Analysis Questionnaire to fill out and return, without obligation, for concrete answers to your specific waste treatment problem. The address—**4918** Stenton Ave., Phila. 44, Pa.

LEEDS LN NORTHRUP
instruments *automatic controls • furnaces*



SCHEMATIC DIAGRAM OF SOLA CIRCUIT modified to supply regulated plate and filament voltages. Regulation on one stepped-up output and two stepped-down outputs is within ±3% for input variations of ±13%. Other units available regulate as close as ±1% for input variations of ±15%.

YOU GET VOLTAGE REGULATION AND MORE FROM A SOLA:

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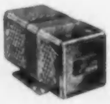
Today's complex electrical and electronic equipment, with its narrow limits for adequate performance, makes a fixed level of input voltage virtually essential. There are many fine voltage regulators available for this duty alone. However, the Sola Constant Voltage Transformer delivers one-to-one, stepped-up, or stepped-down voltages closely regulated. One Sola unit may replace both voltage-regulating circuit or component, *and* conventional power transformer.

The Sola Constant Voltage Transformer is a static-magnetic voltage regulator. It offers many important advantages over other stabilizers which depend solely upon saturation of core materials for their regulating action; or electronic types employing tubes.

To meet the exact requirements of many load devices or service conditions, Sola voltage regulators are available in stock models, or custom designs in production quantities. Your Sola representative will be happy to provide you with information on their feasibility for your particular application.

SOLA *Constant Voltage* **TRANSFORMERS**



Write for Bulletin 26C-CV-170
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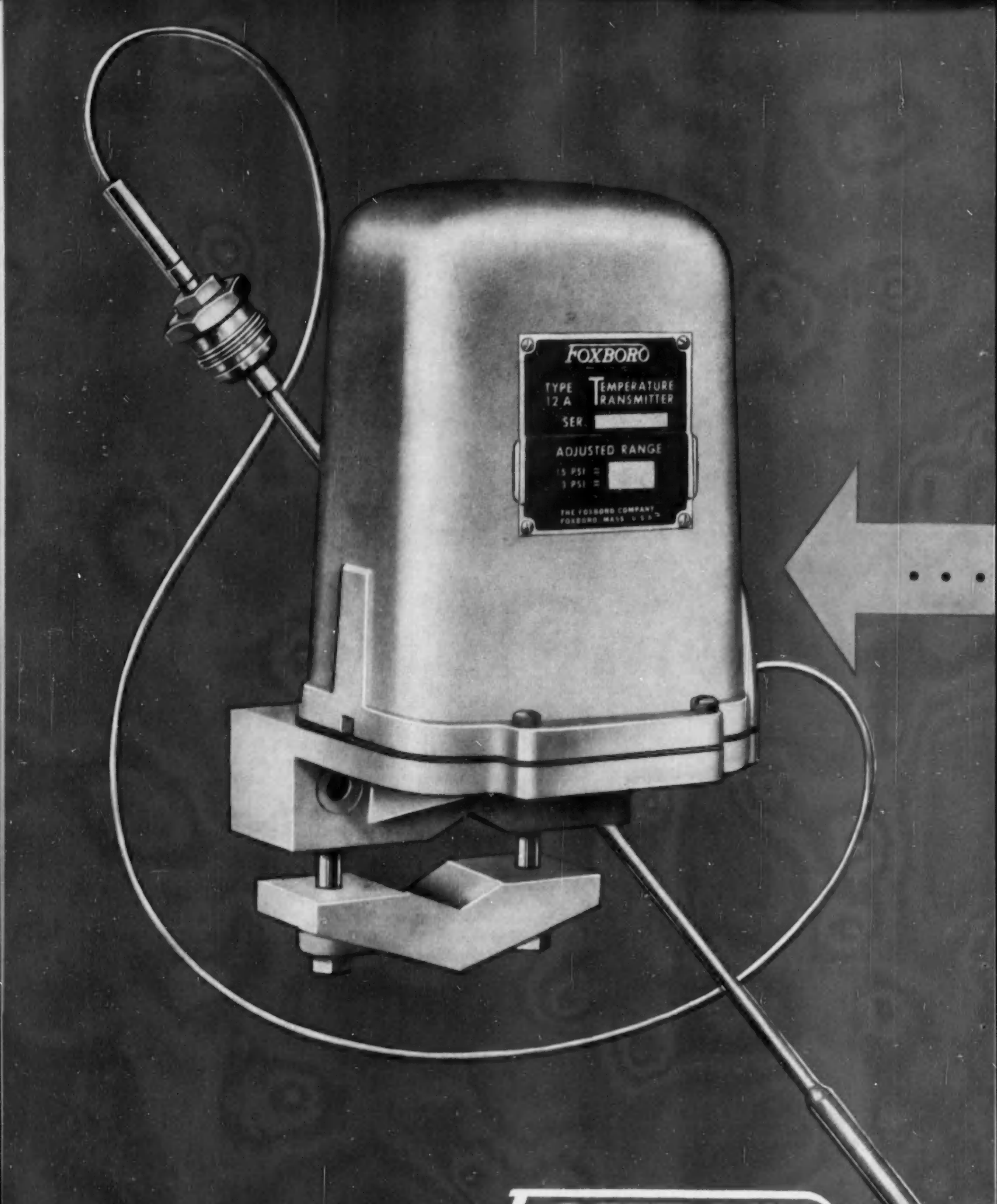
CONSTANT VOLTAGE TRANSFORMERS for Regulation of Electronic and Electrical Equipment • **LIGHTING TRANSFORMERS** for All Types of Fluorescent and Mercury Vapor Lamps. • **SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414** • *NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464* • *PHILADELPHIA: Commercial Trust Bldg., Rittenhouse 6-4988* • *BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3354* • *CLEVELAND 15: 1836 Euclid Ave., PRospect 1-6400* • *KANSAS CITY 2, MO.: 406 W. 34th St., Jefferson 4382* • *LOS ANGELES 23: 3138 E. Olympic Blvd., ANgelus 9-9431* • *TORONTO 17, ONTARIO: 102 Laird Drive, Mayfair 4554* • *Representatives in Other Principal Cities*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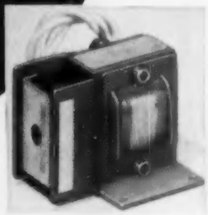
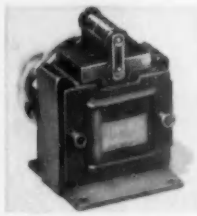
Decco

SERIES 50

INDUSTRIAL SOLENOIDS



Your choice of mounts



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Direct current solenoids

Decco's Series 50 offers more power—longer stroke with the same dependable quality and performance that has made Decco the top name in industrial solenoids.

There is a Decco solenoid for every requirement. Built to give better service for a longer time. Solenoids engineered and modified to your requirements. Let us discuss your problems.

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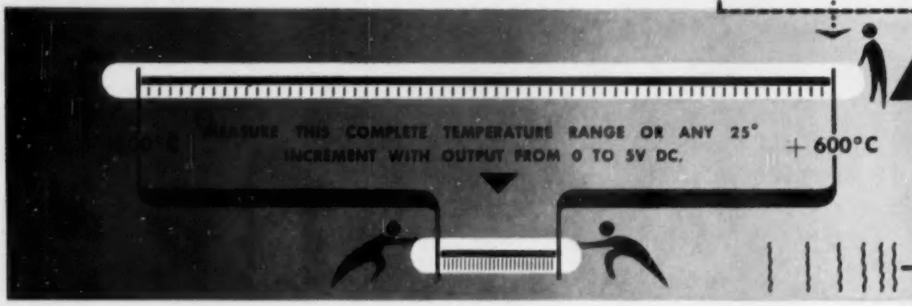
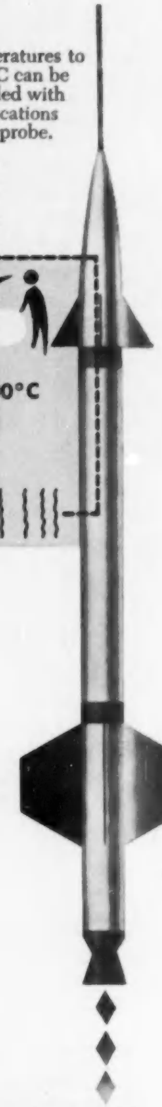
ACCURACY & FLEXIBILITY

Temperatures to 1200°C can be recorded with modifications to the probe.

The RHEEM REL-401 Temperature Measuring System





The Rheem Temperature Measuring system is a sub-miniature modular instrument, designed to fulfill all telemetered temperature measurement requirements within the range of −100°C to +600°C.

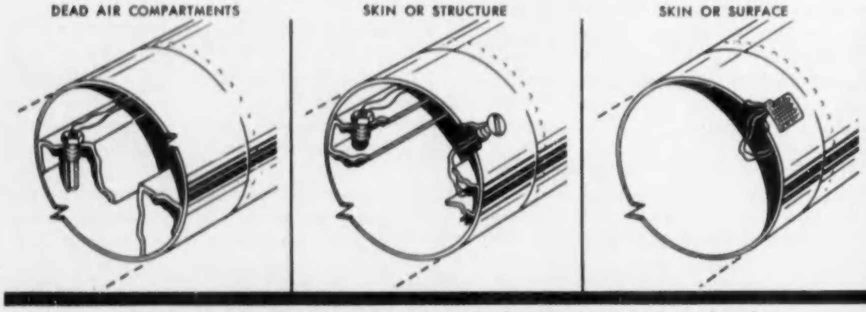
The system is adjustable to obtain a 0 to 5 volt d.c. signal output for any increment of temperature within the −100°C to +600°C range, with a minimum temperature range requirement of only 25°C for 0 to 5 volts output, and a maximum temperature range of −100°C to +600°C for 0 to 5 volts output. This feature permits maximum resolution for all temperature measurements at accuracies up to ±1° C.

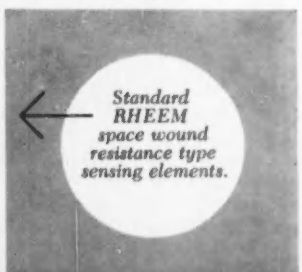
The modular construction of this system provides extreme flexibility in system installations, with maximum economy in space, weight, and cost, in that only the required number of instruments need be provided for the exact number of measurements to be made.

The high level output voltage of the system lends itself to standard commutation procedures for telemetering and also provides sufficient current to drive a 1 ma movement recorder for ground or commercial application.

The sensing probes for this system are platinum resistance of single value and are furnished in many configurations to provide the shortest response time, minimum space, and greatest degree of accuracy for each specific temperature measurement. The output impedance for the REL-401 is 100 ohms maximum.

TYPICAL PROBE APPLICATIONS





Rheem standard sensing elements can be furnished in a variety of probe configurations to suit specific design requirements.

You Can Rely on Rheem

for further information call:

Visit RHEEM at booth No. 309 at the I.R.E. SHOW.
March 19 thru 22, 1956
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RHEEM MANUFACTURING COMPANY

GOVERNMENT PRODUCTS DIVISION

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● A new dual-beam cathode-ray oscillograph with facilities for precise observation, comparison and measurement of two related a-c or d-c signals.

Has two complete vertical amplifiers with response flat to d-c and uniform within 30% to 300 kc. Amplitude measuring on both channels includes 16 ranges from 400 volts full scale to only 4 millivolts for full deflection to scale limits. The most sensitive range permits a-c or d-c measurements in the microvolt region. Balanced input is available on the seven most sensitive ranges.

High-level, accurate, calibrated, linear sweeps; automatic beam gate; sweeps range from 1 sec./inch to 2 usec./inch in 19 steps common to both channels.

X-amplifier provides up to 20 inches of undistorted sweep expansion; external horizontal input to either or both channels.

Observe, compare and measure two related AC or DC signals with the new, high precision

PRICE
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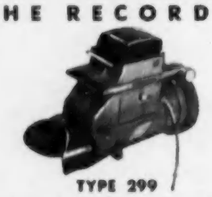
DU MONT TYPE 333
CATHODE-RAY OSCILLOGRAPH

AND FOR THE RECORD...

TYPE 296

Versatile, economical 35 mm general-purpose oscillograph record camera with f/2.8 lens. Price $149.50



TYPE 299

General-purpose recording camera accepts variety of backs for 120 size roll film, cut film or film pack; inexpensively converted into print-a-minute Polaroid Land camera. Price $265.00

TYPE 302

For permanent records in just a minute with Polaroid-Land back; by simple, inexpensive change of backs can be adapted for general-purpose recording with other than Polaroid films. Price $285.00

TYPE 321-A

Continuous motion or single-frame recording on 35 mm perforated or unperforated film or recording paper; film speeds variable in steps from 0.8 to 3600 inches/minute. Price $1050.00

DU MONT TECHNICAL PRODUCTS DIVISION
Allen B. Du Mont Laboratories, Inc., 760 Bloomfield Ave., Clifton, N. J.

Information-gathering costs down 60% . . . test results available in 65% less time! That's the story at Marquardt Aircraft Company's "Jet Laboratory" in Van Nuys, California, since installation of a CEC Data-Processing System. Custom-designed for Marquardt's specific needs, the system helps their engineers evaluate a new ramjet "at a glance". . . helps checkmate troubles at the very outset of testing. It brings true automation to the reduction, listing, compensating, and computation of data, formerly accomplished entirely by manual means.

Dynamic and static testing . . . the function of the Marquardt System . . . is but one of the fields to which Consolidated's Systems Division can bring the *full, combined* benefits of automation and instrumentation. Whether you're interested in such engineering and development testing . . . or in process monitoring and control, chemical analysis, or data processing . . . let CEC's Systems Division look at your problem. The results will pay off for you for years to come.

less time, less cost for product development

Here's how Marquardt's CEC Data-Processing provides *more* data at *less* cost in *less* time . . .

. . . samples 100 channels in 0.25 second or scans an individual channel at any rate up to 1200 samples per second.

. . . automatically amplifies and digitizes temperature, pressure, and flow measurements.

. . . records digital information on magnetic tape for transfer to punched cards or to an electronic computer at whatever rate demanded.

. . . connects any data channel into any or all of three data-presentation modes: recording oscillographs, high-speed digital converter, or remote meters.

. . . generates a precise time base for recording along with data at instant of sampling.

. . . gathers and stores digital information by means of a tape-to-card converter (magnetic-memory drum and relay storage) for utilization by IBM punch.

For more facts on what CEC Systems Engineering can do for you, write for Bulletin CEC 1304-X24.

Systems Division

Chemical Analysis | Process Monitoring and Control | Dynamic and Static Testing

Consolidated Electrodynamics Corporation

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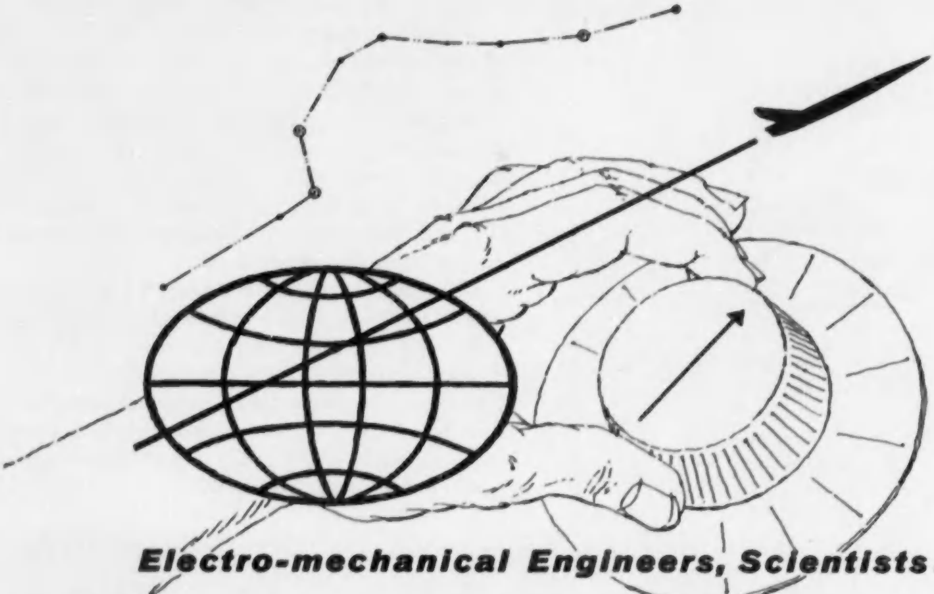
Electronic Instruments for Measurement and Control



Electro-mechanical Engineers, Scientists:

IN TODAY'S ELECTRONIC ACHIEVEMENTS LIE TOMORROW'S CAREERS

Your work in advanced guidance and control systems and components at AUTONETICS today is excellent assurance of *long-range* opportunity. Problems like heat resistance, weight reduction and sub-miniaturization in electro-mechanical devices for missiles and manned aircraft have a direct application to non-military industry.

The work at AUTONETICS is challenging and professionally rewarding. Nearly 100 projects are now underway—most of which have not yet been printed in journals or texts. This diversity means good opportunity to find the field that is best for your particular talent, training and desires.

In developing and designing precision electro-mechanical equipment, you will use the finest digital and analog computers and other advanced research and test facilities at AUTONETICS.

In addition to all the physical advantages at AUTONETICS, you will welcome the professional attitude of your colleagues here. You can expect to be informed about your personal progress, have your ideas listened to.

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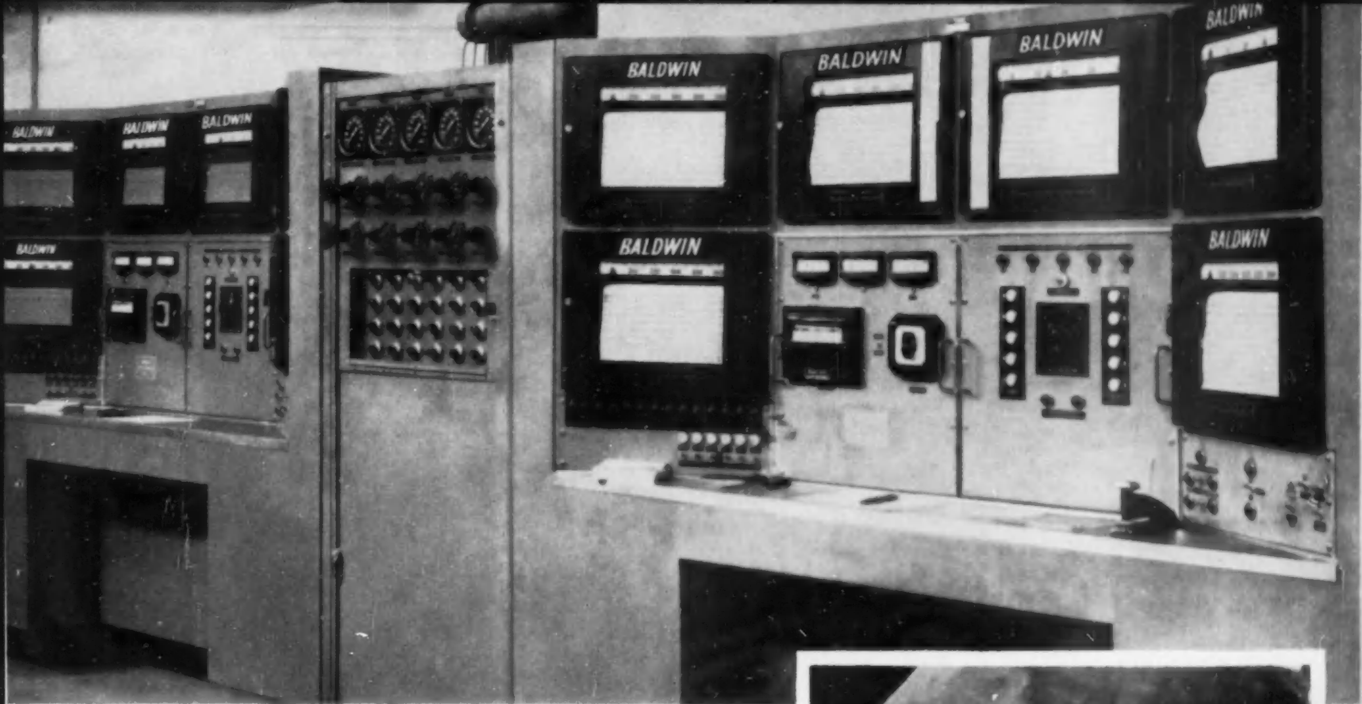
AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE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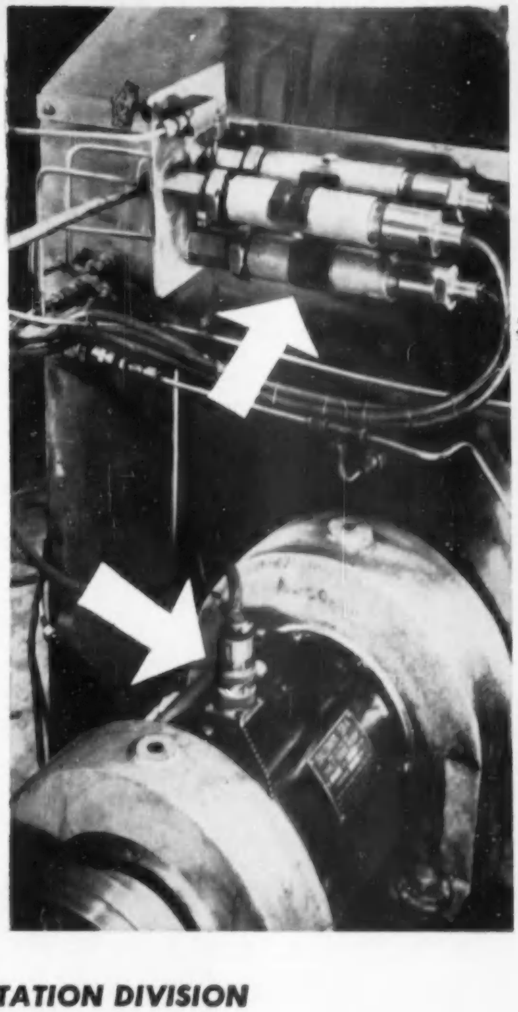

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● As an engineer at IBM, your prospects are virtually unlimited. You work with the world's *largest* computer! And this long-range project offers you the chance to achieve greater satisfaction and growth.

This operation, of front rank importance, and growing by leaps and bounds, requires outstanding men to receive advanced computer training at IBM's Kingston, N. Y. school . . . to undertake responsible assignments in locations throughout the Eastern U. S. Employing the latest computing and calculating techniques and testing equipment, you'll gain experience unequalled anywhere in electronics. And every channel of advancement in this accelerating project will be open to you. The future looks good at IBM, long an outstanding leader in its field.

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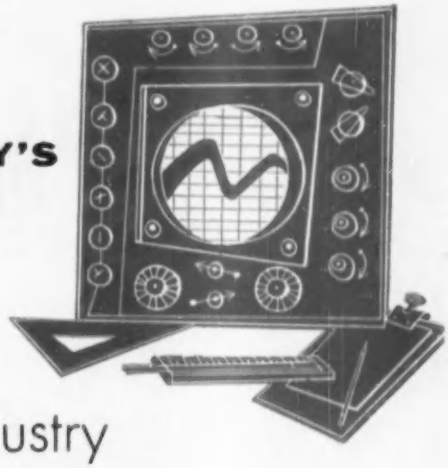


L. A. Control Colossus Girds Cautiously for Industry

Late last year Los Angeles's Chamber of Commerce made a startling disclosure: the annual factory billing for products from its lusty young instrument and control industry is likely to reach $1 billion in 1956. The estimate follows a survey of a specialized manufacturing group that now includes 436 firms employing 72,167 people. In 1941 the local plants in this field could be counted on your fingers—and their annual billings totaled only $47,000.

How much from government coffers?

Not disclosed in the L.A. C. of C. report, however, was just how much of the billion-dollar tab will be picked up by the government—but shrewd guessers suggest defense orders take up to 75 per cent of this local industry's output.

Do Los Angeles control venders consider this military bias a deterrent to healthy growth? H. Leslie Hoffman, chairman of the committee that made the survey and president of the local firm bearing his name, pealed the note of unease when he warned that if the industry is to proceed on a sound economic basis ". . . it must offset its dependence on military business by building up commercial and industrial markets."

Hoffman, whose own company happily sits atop a 50-50 military-civilian market (mainly due to TV products), believes that many primarily military manufacturers will find conversion to the industrial market a major problem. He points out that there are few military items that can be directly adapted for industry. And that frequently, the only adaptable quantity is the "know-how" developed on military projects, rather than the actual designs.

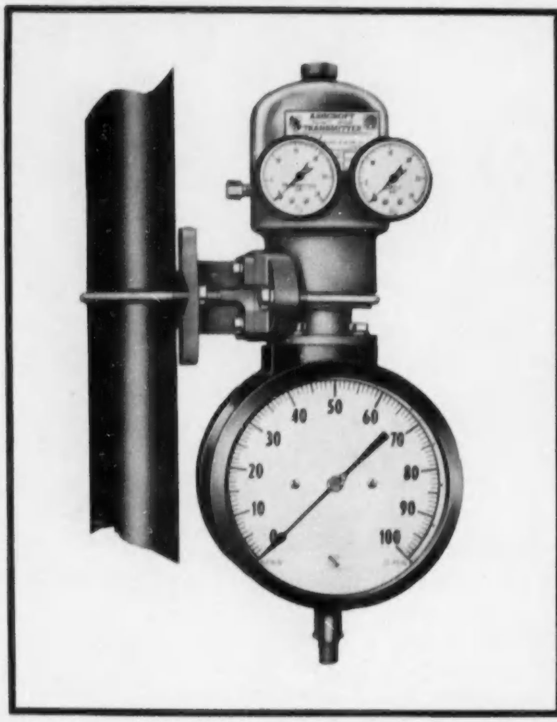
Other companies in the area, while hoping to beef up the industrial side of their business, echo Hoffman's sentiments. Several remember dreaming up a rosy picture of customers lined up to buy military products that were to be released to the civilian market. This proved to be far from the case. Not only was the military hardware of little use to industry, but even the military's approach to new developments was found, with few exceptions, to be utterly different.

Military items sometimes do charm industry

Bendix Pacific, however, cites the example of a military product that it did successfully redesign to meet industrial needs: telemetering equipment. The company has made good inroads

Designed to solve safety and service problems

...THE NEW ASHCROFT PNEUMATIC PRESSURE TRANSMITTER



This new Ashcroft Pneumatic Pressure Transmitter is particularly recommended to processing industries and power stations. It combines speed and accuracy with maximum protection and serviceability.

The new design features the 6" indicating Ashcroft Maxisafe Duragauge, long known for dependable performance. It has an integrally-cast solid metal wall between dial and pressure sensitive element so that the transmitter can measure pressures up to 100,000 psi with complete safety for personnel and equipment. If misapplication ruptures the Bourdon tube, the Teflon-coated back cover serves as a safety blowout relief.

Another outstanding design advantage is easy access to both gauge and transmitter sections. Simply remove the safety-relief back cover and both the gauge and transmitter can be calibrated. Yet a sealed housing makes the entire assembly weatherproof.

The transmitter operates on low-pressure air. No need for expensive high-pressure lines and fittings. Supply air pressure as low as 18-20 psi for 3 to 15 psi output provides especially advantageous operation where electrical wiring might be a hazard. Inflammable, poisonous or corrosive liquids or gases are confined close to their source, away from the central control point.

The Series 1250 Ashcroft Pneumatic Pressure Transmitter is available with pressure sensing elements in all standard pressure ranges and Bourdon tube materials. Installation of the transmitter is easy. Small diameter tubing may be used, and the pipe, stem, wall or flush mounts are interchangeable in the field. Get complete operational data and construction details. Write for Bulletin 340.

YOUR INDUSTRIAL SUPPLY DISTRIBUTOR has the broad knowledge and thorough experience essential to satisfy every requirement of your Ashcroft Pneumatic Pressure Transmitter application. You get fast, economical service from his local stocks.

In Canada: *Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario*

ASHCROFT GAUGES

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

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into petroleum processing, meteorology, flood control—and now finds its telemetering production trend well toward the industrial side. Several other manufacturers have found at least one military-sponsored item that is helping to fatten up industrial proceeds. Coleman Engineering Co.'s Digitizer—developed for military aircraft—is being sold, only slightly revamped, in data-handling systems for oil refineries and public utilities. Librascope has industrialized its digital and analog computers as well as its mechanical integrators and magnetic drums. Litton Industries, Inc., also is selling many of its military items to industry, but it reports a reverse twist: some of the principles used in its industrial-type computers are now finding broad application in the military market.

Can defense also mean business security?

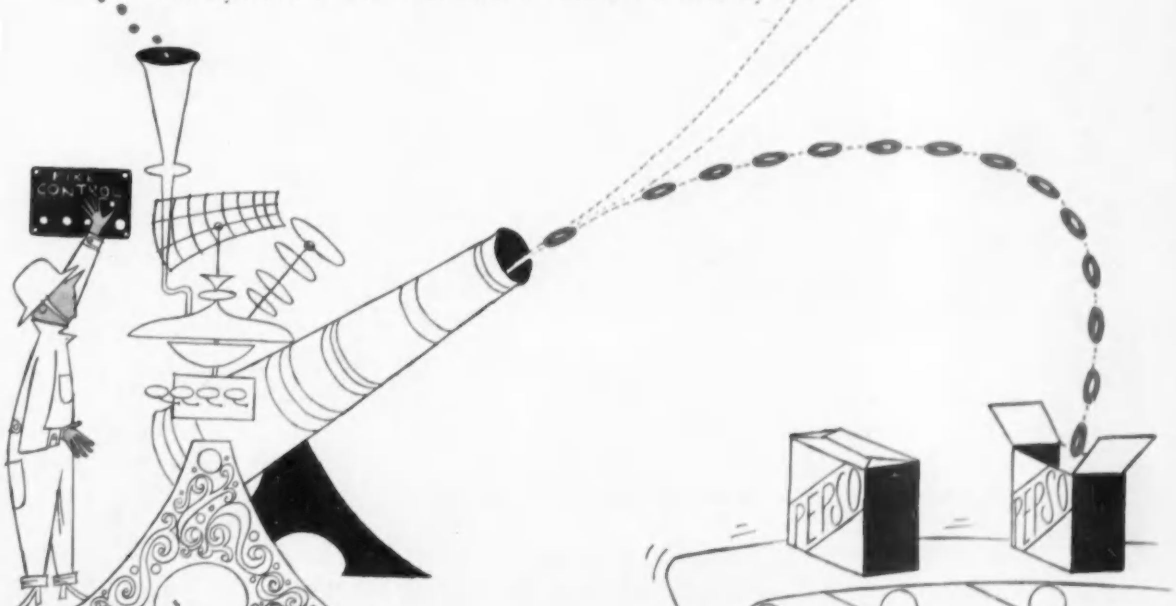
Standing out from the many observations gleaned in Los Angeles interviews are these:

▸ most firms find military items require major redesign for industrial use. Production costs must be cut—but, surprisingly, accuracy must often be increased. Speed and sensitivity are apparently less important in industrial applications.

▸ as a rule, it is not feasible to try to design military items with subsequent industrial use in mind. This may jeopardize product performance—a condition not tolerated by the military.

▸ most companies readily admit that military customers are their "bread and butter" accounts. They have no intention of losing them. Often this has deterred all-out conversion to the industrial market. Many companies hesitate to pull top engineers out of military design to work on civilian projects.

Perhaps the most accurate summary of L. A. control management's attitude toward the industrial siren is contained in this neat joining of two proverbs by one from the ranks: "We have already buttered our bread—but we will not necessarily lie in it."

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Lightweight
Chemically Resistant
Flexible
DEKORON
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harness
Now you can whip high instrument tubing installation and replacement costs in your plant—with Dekoron Poly-Cor®. That's because the chemical resistance of plastic even outlasts expensive alloy tubing . . . because its lighter weight and flexibility make it a snap to install without special tools . . . because you can install practically any number of tubes at one handling, just like electric wiring. You can't lose with Dekoron Poly-Cor — it cuts your investment because of its lower installed cost, cuts your maintenance because it lasts years longer.
Tube up with DEKORON completely
Dekoron products now include single and multiple line metal tubing with plastic coating, multiple tube all-plastic instrument line harness (above), flat 10-tube "ribbon," fittings and junction boxes.
Dekoron products
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DEKORON PRODUCTS DIVISION • MANTUA, OHIO

Control
ENGINEERING
MARCH 1956

Pulling Together

One year ago, in an admonishing editorial, "Let's Pull Together", we sounded a plea for cooperative effort between the technical societies' professional divisions and groups concerned with instrumentation and automatic control. Two months later, in May, we reiterated this plea. And now, as we take up our song again, it's a pleasure to shout kudos, not caterwauls.

First we call forward to take their bows the Instrument and Regulators Division of ASME and the Feedback Control Committee of AIEE. March 26 through 28, '56 they will cosponsor a conference on nonlinear control systems at Princeton University. The conference is scheduled to start with an historical resumé of developments by our regular contributor of book reviews, Professor T. J. Higgins, University of Wisconsin. Then it will swing into a review of physical nonlinearities. Sessions on analysis, mathematical tools, and their applications to significant industrial and military problems will follow. The Princeton campus should provide a relaxing atmosphere for an informal meeting ground of ideas from all corners of our field.

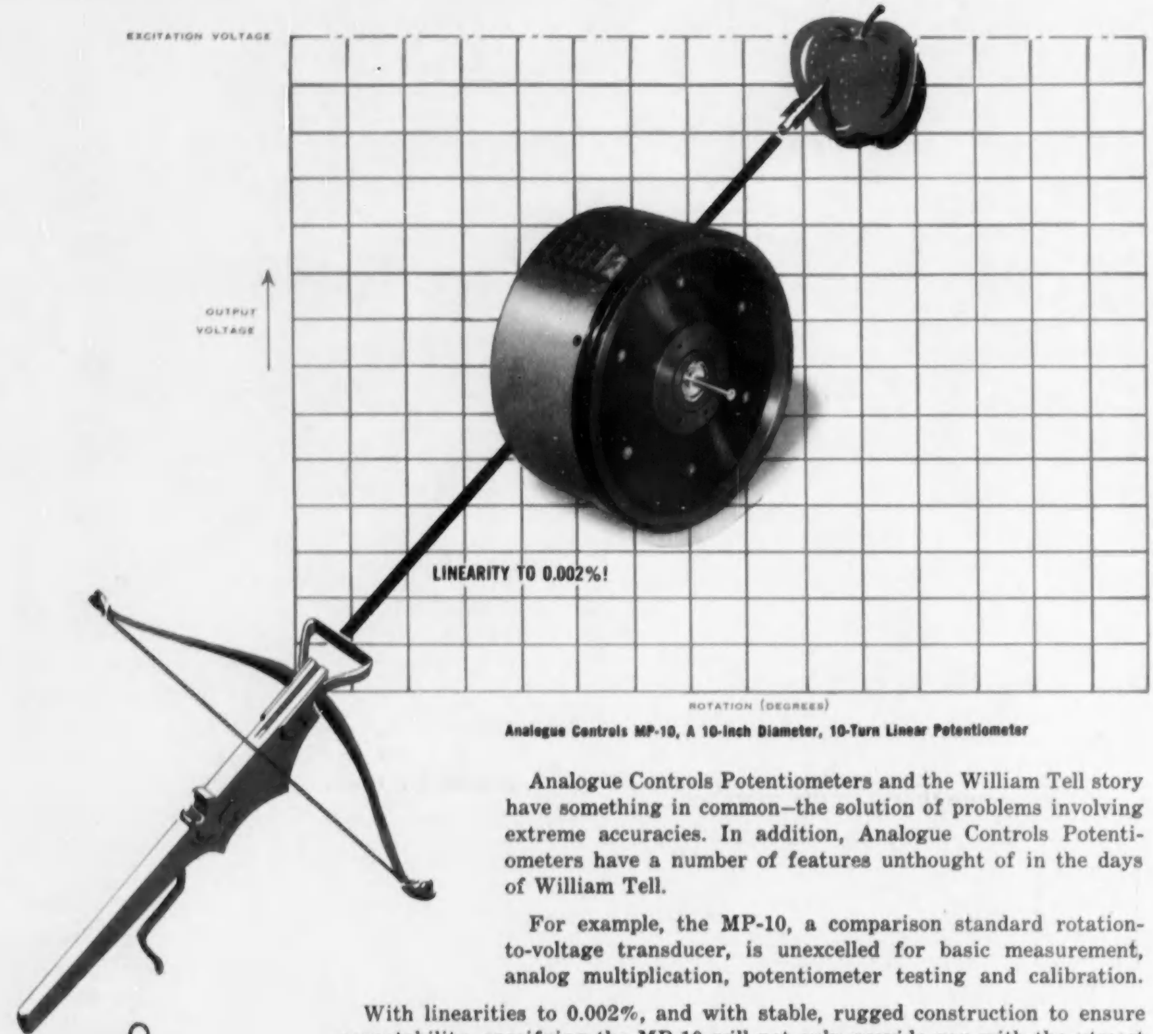
The forging of cross-society links between the educational committees of the professional groups, while still in the formative stage, deserves the next hand. The goal of these committees, which seek to teach the rudiments of control systems technology, is a set of course outlines and training aids that will be available to local sections of any professional society. We suggest that interested readers contact their society representatives or pen us a note.

Our final curtain call goes to the British Institute of Chemical Engineers and the Society of Instrument Technology for their stimulating joint conference on automatic process control last October. Backstaging overworked discussions of control equipment economics and labor union reactions, the conference played up the importance of knowing the characteristics of the operation to be controlled and of having an adequate theoretical foundation on which to erect a design.

While mindful of the Instrument Society of America's continuing program of joint sessions with all of the societies active in our field, this editorial spotlights the cooperative work of societies that are set up to aid the professional development of engineers trained in specific regimens. The examples are proof positive of the cross-industry impact of the control engineer. His participation in cross-society work is a healthy way to further his professional interests.

THE EDITORS

ACCURACY IS THE CRITICAL TEST



Analogue Controls MP-10, A 10-Inch Diameter, 10-Turn Linear Potentiometer

Analogue Controls Potentiometers and the William Tell story have something in common—the solution of problems involving extreme accuracies. In addition, Analogue Controls Potentiometers have a number of features unthought of in the days of William Tell.

For example, the MP-10, a comparison standard rotation-to-voltage transducer, is unexcelled for basic measurement, analog multiplication, potentiometer testing and calibration.

With linearities to 0.002%, and with stable, rugged construction to ensure repeatability, specifying the MP-10 will not only provide you with the utmost in long-term accuracy, but will also minimize equipment "down-time".

In addition to the MP-10, Analogue Controls offers a wide range of extremely accurate potentiometers. Analogue Controls is in step with the current design concept of making immediately available to you potentiometers to fit your system, rather than requiring you to design your system around available components.

Find out more about Analogue Controls Potentiometers by writing or calling today! Literature and personalized technical service are yours for the asking.

With linearities to 0.002% attainable in the MP-10, an electron microscope would be necessary to discern variations from true linearity on a straight-line curve in a full-range plot.

CASE DIAMETER (IN.)

NO. OF TURNS	.875	1	2	3	5	10
1	●		●	●	●	
3			●			
10	●	●	●	●		●
15				●		
20					●	

In addition to the above large variety of immediately available standard potentiometers, Analogue Controls designs potentiometers to meet special requirements.

REMINDER!
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March 19-22 New York
Visit us at Booth 86—Kingsbridge Palace

automatic control systems
automatic control components

Analogue Controls, Inc.

39 ROSELLE STREET, MINEOLA, N. Y.

After the Great Ford Foundation Gift . . .

What Still Remains To Be Done To Provide Decent Faculty Pay

The Ford Foundation's gift of a half billion dollars to our privately supported colleges, medical schools and hospitals, now being distributed, is magnificent. But it will be much more magnificent if it inspires completion of the job to which it gives a lift. So far as the colleges and universities are concerned, this job is primarily to rescue their faculty members from being second-class citizens economically.

Even in a period when we have become accustomed to astronomical financial figures, a half billion dollars remains an eye-popping gift. In fact, it is so imposing that a good many people who don't read the fine print are apt to conclude that it must just about solve the financial problem to which it is addressed.

Goes Only a Small Way

However, we have allowed college professors to fall so far behind the parade financially that the share of the Ford half billion dollar gift going directly to the improvement of faculty salaries ($210 million) will go only a small way financially toward doing what is necessary to provide adequate salaries.

Completion of this job for our privately supported colleges and universities calls for:

1. An increase in faculty salaries at least five times as great as that made possible by the Ford gift merely to restore salaries to their 1939 purchasing power level and an increase fifteen times as great to provide adequate salaries today.

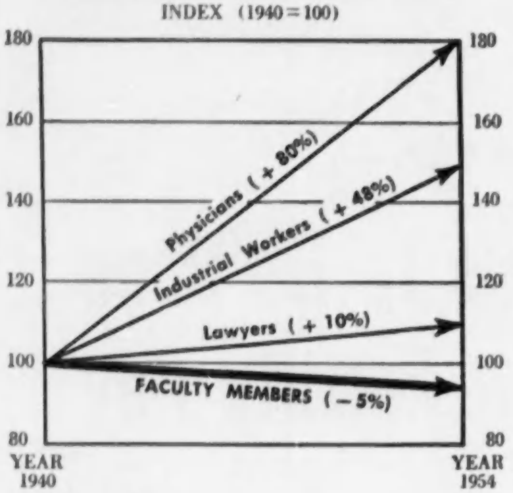
2. Some difficult and courageous decisions by the heads of the colleges and universities in apportioning the grants received by them.

Terms of Gifts to Colleges

The $210 million of the Ford Foundation gift going specifically to improve faculty salaries is being distributed on the following basis: Each of 615 privately supported, regionally accredited liberal arts and science colleges and universities receives a gift about equivalent to its last year's teaching payroll. For ten years only the income from these gifts is to be devoted to raising faculty salaries. After that all the money can be spent in any way the institutions receiving it see fit. There is no requirement that universities having other than liberal arts and science schools limit use of the gifts to improving salaries in these schools alone. They can spread it right through all their faculties if they wish.

In addition to the gift of $210 million specifically directed to increasing faculty salaries, another gift of $50 million goes to a group of 126 institutions selected for specially noteworthy leadership in improving

What's Happened to College Faculty Salaries*



* Real Income before Taxes.

Source: Council for Financial Aid to Education, U. S. Dep't of Commerce: U. S. Dep't of Labor.

the status and pay of teachers. For these schools the individual gifts add about 50% more to the amounts coming from the $210 million fund. They can be used to improve faculty salaries if the institutions choose to do so, but this is not required by the terms of these gifts.

The $210 million plus the $50 million should yield an income of $10-$13 million a year. Even if all this is used to raise salaries, it will be only a small step, however worthy, toward the $200 million per year the colleges need to meet their salary requirements adequately.

Helps Some Who Need It Most

In focussing its gift to improve faculty salaries in privately supported liberal arts and science colleges, the Ford Foundation aims at least part of the help at the spot where it is most desperately needed. Numerous surveys have indicated that the most poorly paid of all college and university faculty members are those in small, privately endowed liberal arts colleges.

But the overshadowing fact is that the teachers in our colleges and universities as a whole are badly underpaid. Just how badly is indicated by the chart above which first appeared in an earlier editorial. (Figures later than those for 1954 are not available.)

The Ford gift will turn the indicator of faculty salaries, which now lies far below the general salary trend, upward a few points. And it will do this in some places where salaries are below the wretched average shown by the chart.

But the Crucial Test Remains

College and university administrators will have the opportunity to extend further the process of getting the help provided by the Ford Foundation gifts where it is most needed. In general, this will mean giving it to senior faculty members, in order to hold experienced teachers and make college teaching attractive as a career. But to make such a division in many schools will take extraordinary fortitude.

The crucial test of the success of the enterprise of the Ford Foundation in raising faculty salaries will lie in whether it prompts the rest of us — college alumni, individuals, business firms and legislators alike — to see that it is a great beginning, not a signal for a recess.

Even with the Ford gifts providing $10-13 million a year, our privately supported colleges and universities must have an increase of about $190 million a year to provide decent faculty salaries.

This is a job far beyond the capacity of the Ford Foundation, imposing though that is. It is a job far beyond the capacities of a few hundred large corporations and a few thousand wealthy individuals. If it is to be done, it is a job at which all of us must work with a will.

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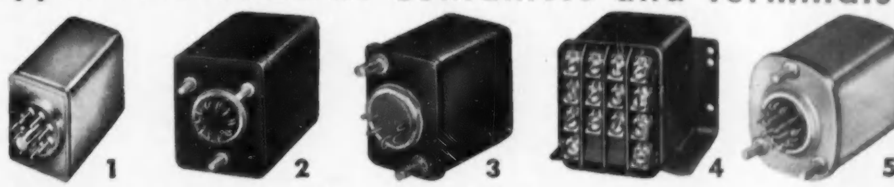

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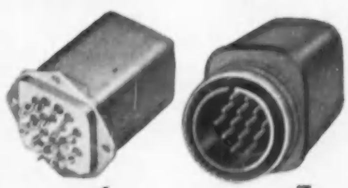

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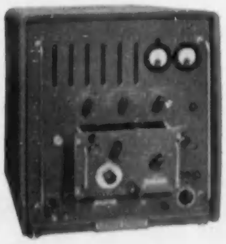

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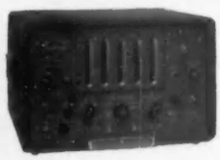

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Position Versus Tachometer

Speed-matching Systems

THE GIST: In the web process industries—textiles, paper, board-forming, synthetic fiber, etc.—succeeding sections of the processing machine must be controlled so that the processed material doesn't break or pile up between sections. If the material is strong enough, this can be accomplished by controlling the tension between the stands. But if the material is weak, and it is impossible or undesirable to hold tension, the elongation ("stretch" or "draw") of the processed material must be regulated. This is done by accurately matching the speed of the stands or sections over their operating range, thus keeping the ratios of the various roll speeds at the desired values.

At the present time, two basic systems are used to match section speeds in electrically driven processing machinery: *position* speed-matching systems, and *pilot-generator* (tachometer) speed-matching systems. Each has its advantages and limitations. The position technique is more accurate, but the pilot-generator technique is cheaper and takes up less room. Read the following to find out which one fits your application.

M. H. FISHER,
Industry Engineering, Westinghouse Electric Corp.

The names of the two types of speed-matching systems pretty well describe their operating characteristics. In a position speed-matching system, the angular position of the driven roll of a particular section is compared with the angular position of a master reference motor-generator set, or with the angular position of the driven roll of another section. The comparator is a mechanical differential mechanism, and its output (or error signal) is converted to an electrical signal and then amplified and used to regulate the shunt field of the drive motor to align the regulated roll with the reference. This system is highly accurate since the regulated sections and the reference are locked together. The absolute speed of the rolls is varied by changing the output frequency of the reference motor-generator set or by changing the speed of the lead section (depending on the specific system used), while the speed ratios between rolls are varied by changing the belt position on a special set of cone pulleys as described later. Figure 1 shows a drive motor and differential position speed-matching equipment of a paper machine.

In pilot-generator systems, the speed of the rolls is matched by comparing the output of a generator or tachometer on the regulated roll with a common reference for all the rolls. The various sections are not locked together as in the position speed-matching system. The steady-state matching accuracy depends on the identical characteristics of the tachometers, and the stability of a draw-adjustment rheostat, used to modify the common reference signal to each section so that the speed ratios can be varied. Absolute speed is changed by adjusting the common reference signal. In a purely proportional system, there is an additional constant velocity error under steady-state conditions that is proportional to the load on the section. For this reason, integral (or reset) control is often added to improve steady-state accuracy. Although less accurate, this system is cheaper and more compact than the position speed-matching system. The complete control system is

electrical, and the comparator is mounted in the control cabinet. Figure 2 shows a section of a press drive on a paper machine using a pilot-generator speed-matching system.

Table I lists the advantages and disadvantages of the two systems. These points are covered in detail in the discusion that follows.

Position Speed-matching Systems

Figure 3 shows a schematic of a typical position speed-matching system. The common reference standard is the adjustable frequency output from a small alternator driven by an adjustable-speed dc motor. The common alternator drives a small synchronous reference motor on each section controller and each synchronous motor provides an angular position reference for each controlled roll. As mentioned previously, the absolute speed of the whole machine can be changed by changing the speed of the alternator dc drive motor.

If only two sections of a processing machine are to be speed-matched, or if speed-matching is required from start-up (sections at rest) conventional torque synchros can be used to transmit an angular reference between the two rolls. This modification is shown in Figure 4. A synchro transmitter is attached to the shaft of the lead-section drive motor, and a synchro receiver to the differential cone (instead of the synchronous motor). In this case, absolute speed is changed by varying the speed of the lead-section drive motor.

The differential error detecting unit shown in the dotted box of Figure 3 serves two purposes. It generates an error signal proportional to the difference between desired speed and actual speed, and it makes it possible to maintain a constant ratio between desired speed and reference speed. The comparator is a mechanical differential as detailed in Figure 5. The sun gear of the differential is driven by the reference synchronous motor, while the ring gear (integral with the differential cone) is belt-driven at a speed proportional to the speed of the regulated section. The planet gear on the differential crank rotates in its own bearings during

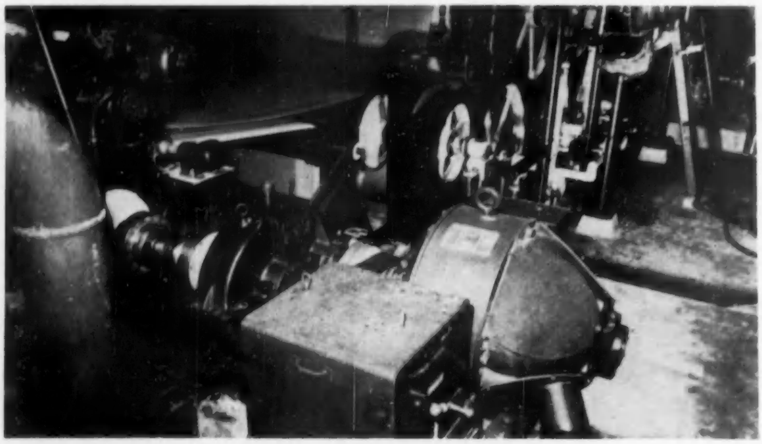


FIG. 1. Position speed-matching equipment on a paper machine.

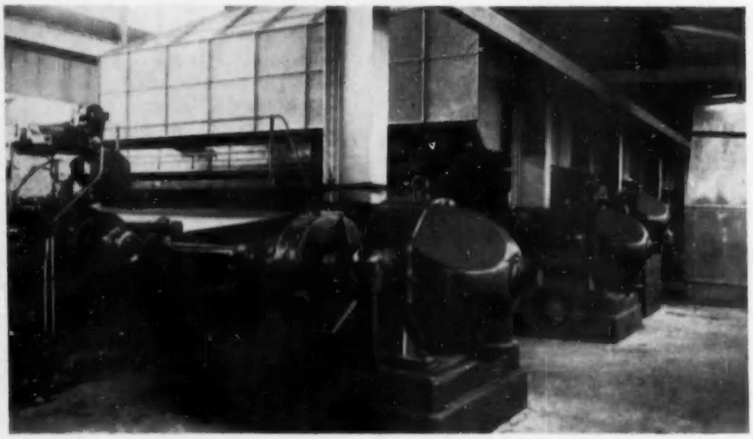


FIG. 2. Pilot-generator speed-matching equipment on a paper machine.

TABLE I HOW THE TWO SYSTEMS COMPARE

POSITION SPEED-MATCHING SYSTEMS

ADVANTAGES	DISADVANTAGES
1. Relative speed between sections accurately maintained since sections are locked together.	1. Requires relatively large space near machine.
2. Changes in system amplification do not affect speed regulation.	2. Requires more mechanical parts.
3. Position-error signal and rate of change of error signal both used.	3. Relatively high cost because of use of precision parts.
4. Operation can be inspected visually.	
5. Maintenance requirements are low and restricted to mechanical components.	

PILOT-GENERATOR SPEED-MATCHING SYSTEMS

ADVANTAGES	DISADVANTAGES
1. Requires small space near machine.	1. Pilot-generator inaccuracies cause trouble.
2. Low cost because of few precision parts.	2. Load changes result in a continuous error.
	3. Magnitude of error varies with system amplification.
	4. Malperformance is not readily detected.
	5. Tracking is difficult.

steady-state conditions, and moves in space only when the reference speed or desired speed (ratio) is changed, or when the actual speed varies due to loading variations. Thus the change in angular position of the differential crank represents an error signal proportional to the difference in actual and desired speeds.

The ratio of desired speed to reference speed is changed by changing the position of the belt on the tapered differential and drive cones. Belt position can be changed manually by means of a crank on the lead screw, or remotely by means of a conventional angle-repeater synchro system (similar to that shown in Figure 4 for angular reference transmission). A plus or minus 12.5 per cent draw adjustment is usually provided in the taper of the cones, to permit draw or stretch adjustments and to compensate for reduced roll size after machining.

The error signal represented by the change in angular position of the differential crank is transmitted by gearing to both speed and motion-sensitive transducers. The position-sensing device is a small rotary transformer similar to an induction regulator. It produces a signal voltage proportional to its angular offset from a null position. Rotary transformer angular travel is limited to about 55 electrical deg for the regulating range, Figure 6, by means of limit stops and a slip clutch on the rotor shaft.

Differential crank angular velocity is sensed by a small dc generator. The rotary transformer and dc generator are in motion only during the correction period. Under steady-state conditions, the only moving elements of the error detecting unit are the cone pulleys and the synchronous motor. The reliability of this unit has been proven by more than 300,000 operating hours, with less than 0.001 per cent down time from causes attributable to the differential comparator mechanism.

As mentioned previously, draw or stretch adjustment is accomplished by changing the position of the belt that connects the two cone pulleys. Slack take-up can be accomplished by pushbutton-operated magnet coils that cause a momentary shift of the cone pulley belt.

The two signals produced by the error detecting unit are fed to a control unit consisting of a two-stage magnetic amplifier, which furnishes controlled excitation to the shunt field of the regulated section generator (or motor, in the case of a single-generator system). This control unit, Figure 7, also includes control transformers, dry-plate rectifiers, calibrating

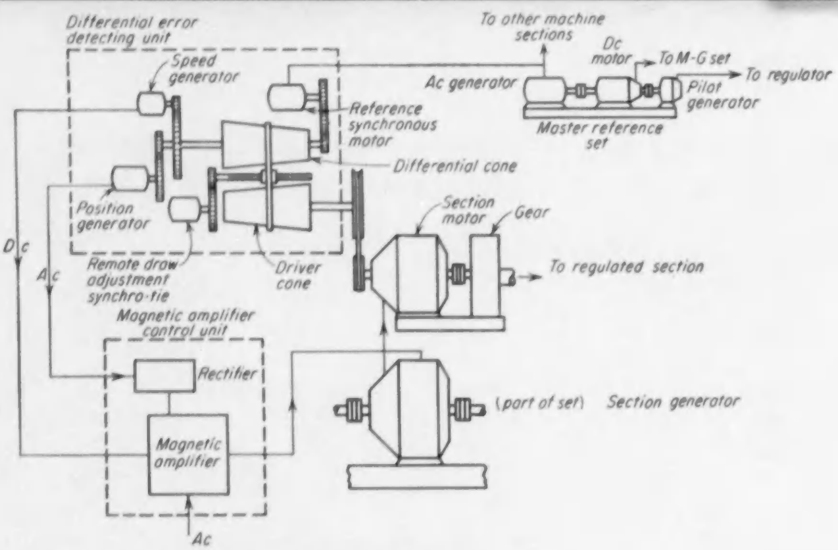


FIG. 3. Schematic of typical position speed-matching system.

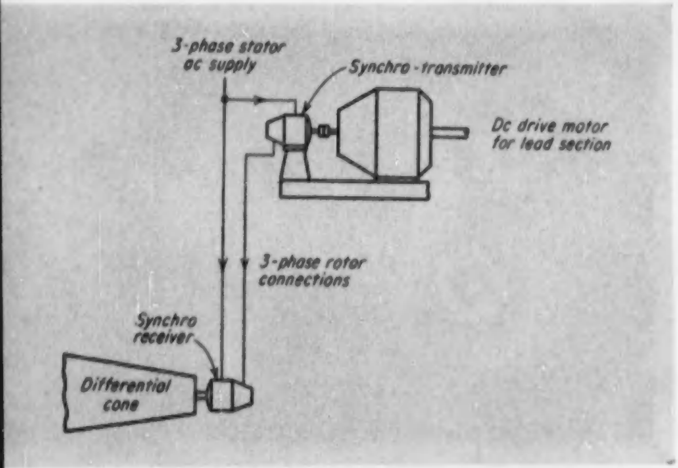


FIG. 4. Modification of Figure 3, with a synchro system substituted to get two-section speed matching.

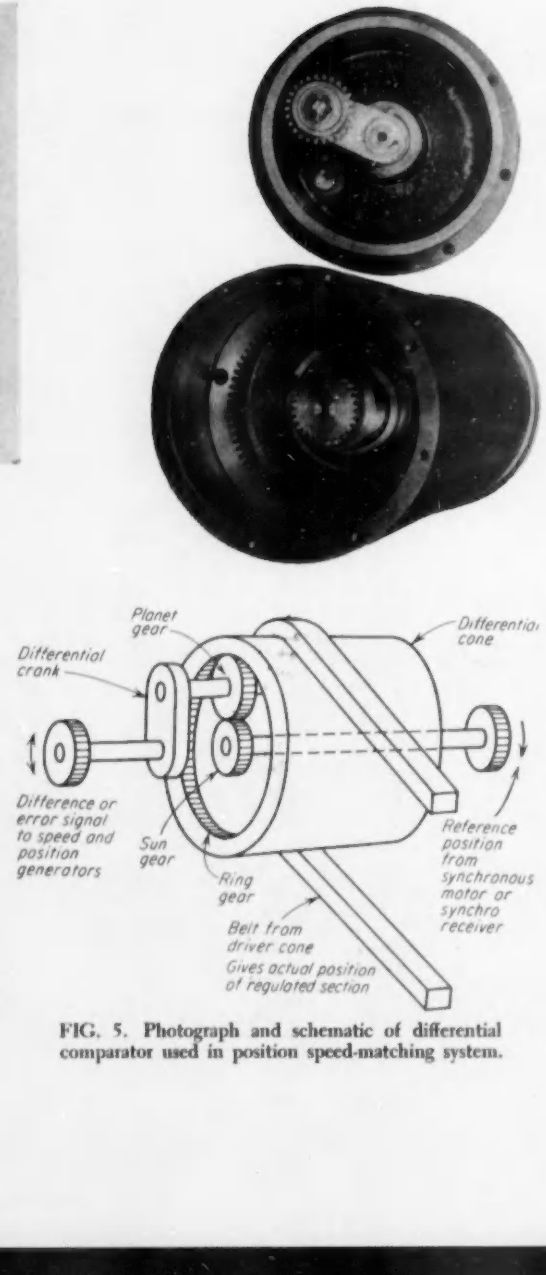


FIG. 5. Photograph and schematic of differential comparator used in position speed-matching system.

resistors, and damping transformers for stabilizing purposes. The regulator constants are selected so that speed-signal amplification is high compared to position-signal amplification. This is comparable to a high-level anticipation or error-rate signal, so that when load changes occur, considerable forcing is obtained to restore the regulated section to its original speed.

Following a load change, the output shaft of the error detecting unit will assume a new angular position, Figure 6, and the section will change its angular position relative to the other sections. But the sections are actually locked together in speed relation by the regulator. Position errors are not cumulative, and once a new angular position is assumed, the rolls or other driven members will

maintain their relative speeds with respect to each other. Actually, the differential comparator gives an integrating action. Even with a dead zone, any minute difference in speed between the differential cone and the reference synchronous motor will slowly increase the error signal until it becomes large enough to cause corrective action by the regulator. A similar result is obtained with the pilot-generator system by adding integral control.

Thus, changes in amplification in the position-signal loop will cause the regulator to operate at a modified position, and as shown in Figure 8, the steady-state accuracy of the regulator is not affected. Changes in amplification in the speed-sensitive loop cause a variation in the forcing effect of the magnetic amplifier regulator circuit, but only the response time to a load change is affected. Even gain variations of as much as plus or minus 25 per cent do not seriously affect the operation of the regulator. This far exceeds the gain variation of the magnetic amplifier regulator.

Usually the control system is operating satisfactorily if the rotary transformer is near the center of its travel range and there is no motion of the differential output shaft. On the other hand, if the position transformer is at either end of its stroke, or if the differential output is moving under steady load conditions, something is probably wrong. These simple criteria permit the machine operator to check regulator performance without the assistance of an electrical maintenance man.

Pilot-generator Speed-matching Systems

Figure 9 shows a schematic of a typical pilot-generator speed-matching system. The common reference signal is modified by the draw-adjustment rheostat and bucked against the output of a precision ac or dc generator on the shaft of the regulated section. The relative speed between sections is changed with the draw-adjustment rheostat, and the absolute speed is changed by varying the common reference signal. When a load change occurs, the error signal changes regulator output to correct for the speed change that results from load change. Since an increased error signal is required to increase regulator output, there is a constant velocity error proportional to the load on the regulated section, Figure 8. This causes a variation in the draw or stretch between sections. This variation is proportional to the error signal and consequently to the load on the sections. As mentioned previously, integral control is added to improve the steady-state accuracy of pilot-generator systems. With these systems, accurate speed control can be maintained under steady-state conditions if the components are chosen wisely and system amplification is sufficiently high.

The main component in any pilot-generator system is the precision tachometer. The accuracy of both ac and dc tachometers is affected by end

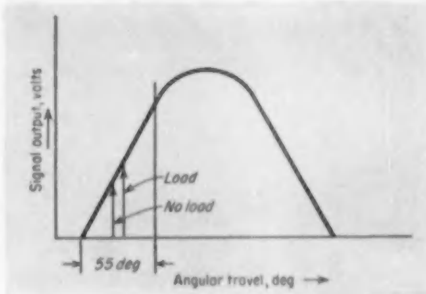


FIG. 6. Output of rotary transformer (also known as induction potentiometer) is a sine wave. Angular travel restricted to keep on linear part of curve.

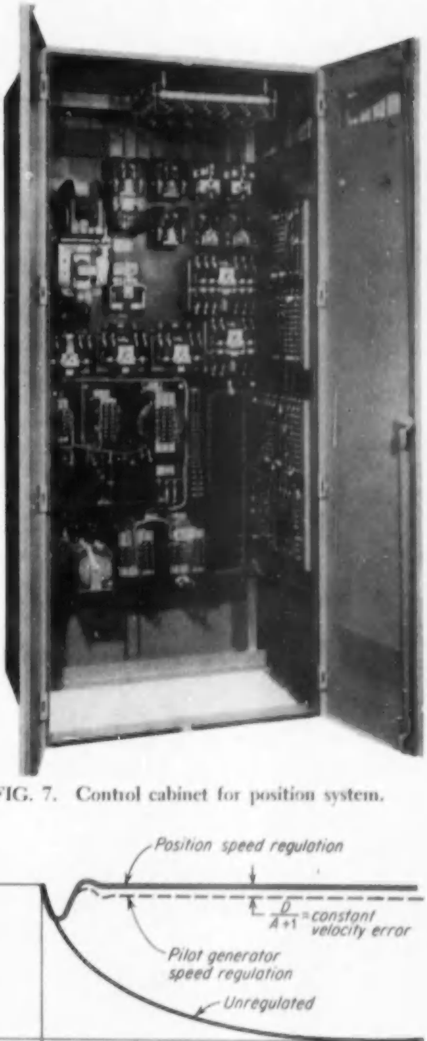


FIG. 7. Control cabinet for position system.

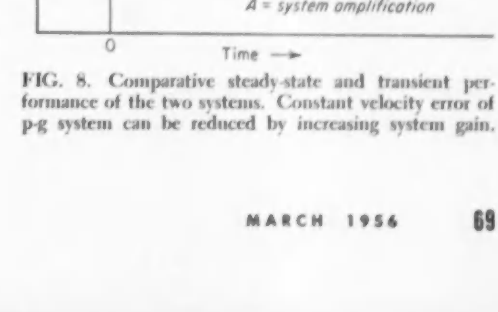


FIG. 8. Comparative steady-state and transient performance of the two systems. Constant velocity error of p-g system can be reduced by increasing system gain.

play, out-of-round bearings, nonuniform air gaps, and other mechanical inaccuracies. In addition, the commutator in dc generators introduces brush contact variations as well as commutator ripple. Dc tachometer inaccuracies increase with increasing load, primarily because of changes in contact drop at the brushes. In systems designed to be accurate within 0.1 per cent, at least a 1 megohm load is used with dc tachometers. Ac tachometers show improved accuracy, and are not as sensitive to load change. But the ac tachometer output must be rectified, and errors may be introduced here. Other mechanical errors, such as those listed above, affect both types of tachometers and are usually erratic and difficult to locate.

Pilot-generator system accuracy drops off as the speed of the machine or driven member decreases, since approximately the same numerical change in speed with load is necessary to signal the amplifier and the magnitude of both the standard and tachometer speed signals decreases proportionately with speed. While system amplification increases at low speeds by the ratio of the change in slope of the generator saturation curve, the net result of these changes is that regulator accuracy decreases at low speeds. With a 5 to 1 speed range, regulation accuracy is about 0.25 per cent at low speeds in a pilot-generator system designed to be within 0.1 per cent accurate at top speed.

Amplifier variations, such as "drift", comprise another source of error that can cause unwanted changes in the actual speed of the section. These variations are particularly objectionable in the dry end of a paper machine between the drier and calender sections, or between two calender sections, where speed variation causes tension variation. In locations such as this, a 2 per cent change in relative speed changes the tension in the paper from zero to the breaking point. Sometimes these variations are overcome by using tensiometer devices.

The integrating amplifiers, introduced to improve steady-state accuracy, are also subject to drift, so that errors are introduced from this source as well as from the reference and the tachometers. Maintenance requirements are also increased by the addition of more regulator components, usually including a multivibrator and several tubes.

Unlike the position speed-matching system, malfunctioning of a pilot-generator system is not easy to detect. Sensitive meters manned by competent personnel are required. Erratic sources of trouble, such as loose wires and high-resistance grounds due to moisture conditions, are particularly difficult to locate. Since the pilot-generator system requires a continuous

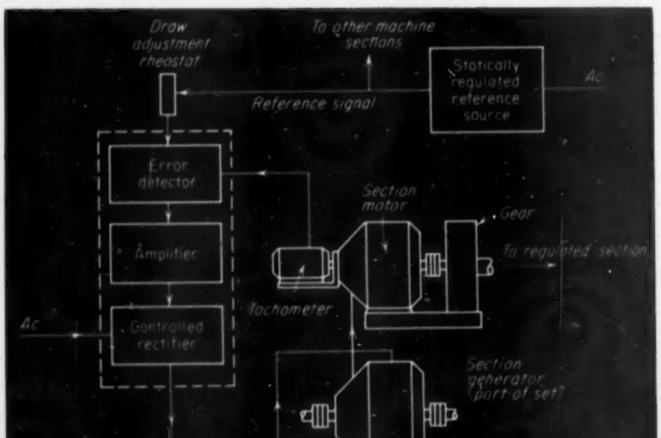


FIG. 9. Schematic of typical pilot-generator speed-matching system.

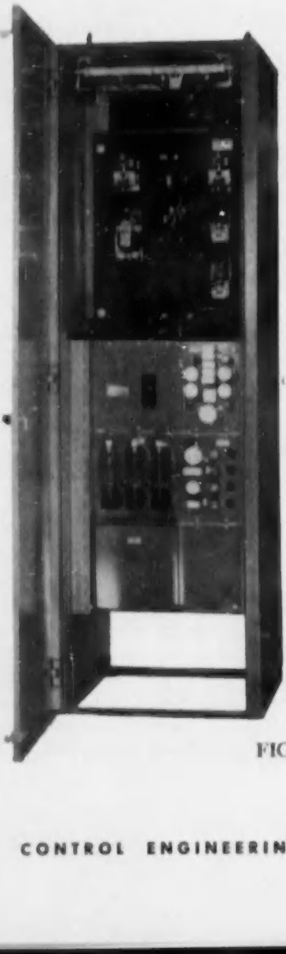


FIG. 10. Typical control cabinet for a pilot-generator speed-matching system.

PERFORMANCE VS. COST?

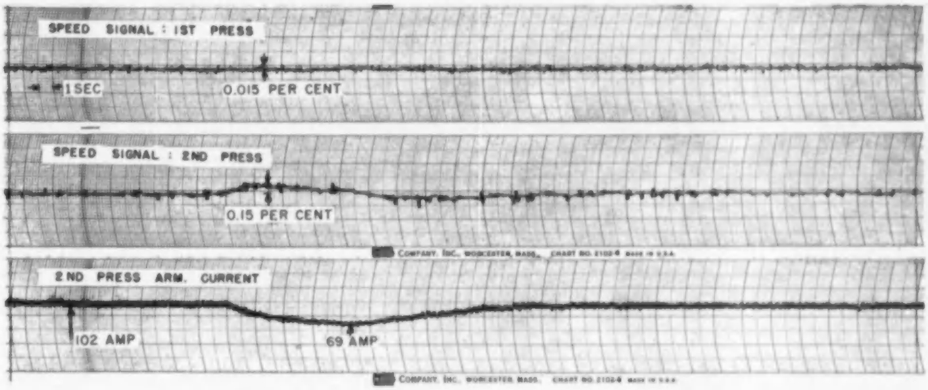


FIG. 11. Test results showing effect of load change on a position speed-matching system.

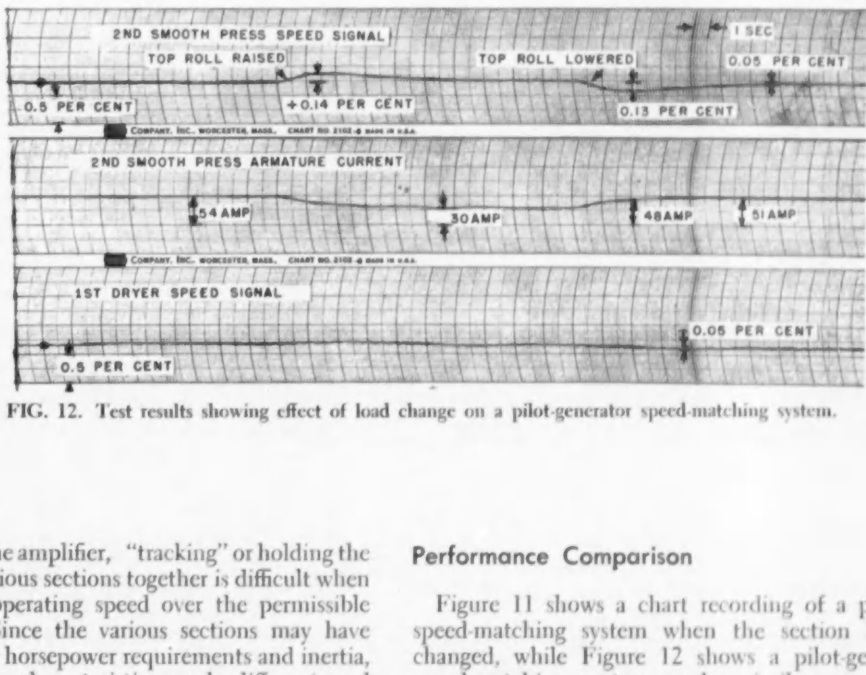


FIG. 12. Test results showing effect of load change on a pilot-generator speed-matching system.

error signal to the amplifier, "tracking" or holding the speed of the various sections together is difficult when adjusting the operating speed over the permissible speed range. Since the various sections may have widely different horsepower requirements and inertia, the section motor characteristics may be different, and the section amplifiers are likely to have different output performance curves over the speed range of the system.

Low cost is the prime advantage of pilot-generator speed-matching systems, with small size a secondary feature. Figure 10 shows a typical control cabinet for a paper mill pilot-generator system. Notice that it occupies about the same space as the control cabinet for a position system shown in Figure 7. The position system, however, requires additional floor space for the differential mechanism.

Performance Comparison

Figure 11 shows a chart recording of a position speed-matching system when the section load is changed, while Figure 12 shows a pilot-generator speed-matching system under similar conditions. Notice that the steady-state accuracy of the position system is better (0.015 per cent for position system versus 0.05 per cent for pilot-generator system), but that the transient variation is about the same (0.15 per cent for position system versus 0.14 per cent for pilot-generator system). When considering the two systems in their entirety, position-regulating systems are preferable for speed-matching if performance is critical. If cost is the more important factor, or space near the machine is at a premium, pilot generator systems may be the better choice.

Selecting Power-control Valves

I. THEIR AIR-OIL CHARACTERISTICS

THE GIST: High performance at high power levels is more and more in demand from smaller and smaller control packages, especially in the aircraft and machine tool fields. Variable displacement pumps, prime movers, and sumps often must be located remote from the load because of limited space. This means more line compliance and lower dynamic performance. Hence, series valves are being used more widely to directly control high-power loads. When this is the case, low efficiency is the price of high performance: the valve must dissipate some of the power that it receives from the supply. Heat exchangers may be needed to cool the hydraulic fluid.

This article describes the important characteristics of the various valves that can control fluid power. An accompanying table compares hydraulic and pneumatic media for valve-controlled drives.

Next month, the authors wrap up their discussion by designing, for oil and for air, the same type of valve-controlled servo drive.

J. L. SHEARER and S.-Y. LEE
Massachusetts Institute of Technology

A valve-controlled hydraulic drive requires less stroke and lower force at the input than a variable-displacement pump drive of comparable power output. For example, to deliver 10 hp to the load, the latter needs about plus or minus 0.5-in. stroke at a maximum force of about plus or minus 200 lb, while a valve needs only plus or minus 0.030-in. stroke at a maximum force of plus or minus 50 lb.

Valve-controlled pneumatic drives for high power levels have been developed for pressure levels up to 2,000 psi and temperatures (short time operation) up to 2,400 deg F. Though the dynamic performance of such drives is good, their static performance and low frequency performance are sometimes hampered by coulomb friction. This coulomb friction is the result of quiescent leakage, which subtracts from the inflow and increases the valve stroke necessary to reverse the load.

HYDRAULICS VS. PNEUMATICS

The relative merits of pneumatic and hydraulic fluids are compared on page 78 for a valve-controlled ram (see Figure 5) with an inertia load and a constant-pressure supply.

The variable orifice is the simplest fluid-power modulator. A very small valve motion can cause a large change in resistance to flow. But the pressure drop across the valve is not a linear function of flow. Figure 1 shows some typical valve designs.

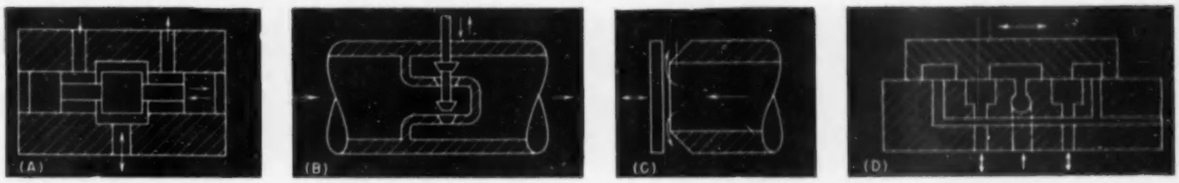
The simple relief valve in Figure 2A makes effective use of a single variable orifice to by-pass flow not required by the load. Flapper and poppet valves can control air flow in low-pressure pneumatic systems, Figure 2B, because the mechanical forces necessary to move the flapper against the low-pressure air are easily supplied by most transducers that have a mechanical output.

Four-way valves have four orifices that act in unison. They are often used to get reversing action in simple on-off control systems like the one in Figure 3. The simple valve in Figure 4 is widely used when very precise flow control is not needed.

Note: Some of this material will appear in Fluid Power Control *(MIT-John Wiley & Sons, Inc.).*

SOME TYPICAL VALVE DESIGNS

FIG. 1.



Three-way spool valve. Balanced poppet valve. Flapper valve. Four-way sliding-plate valve.

FIG. 2.

Single orifice valves
(A) A simple relief valve, and
(B) A flapper-controlled pneumatic force amplifier.

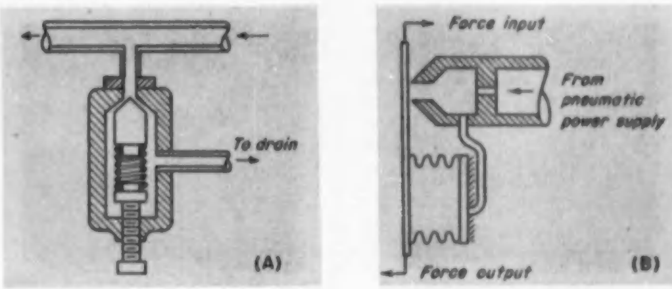


FIG. 3.

Dog-operated four-way valve as used to reverse machine-tool work table.

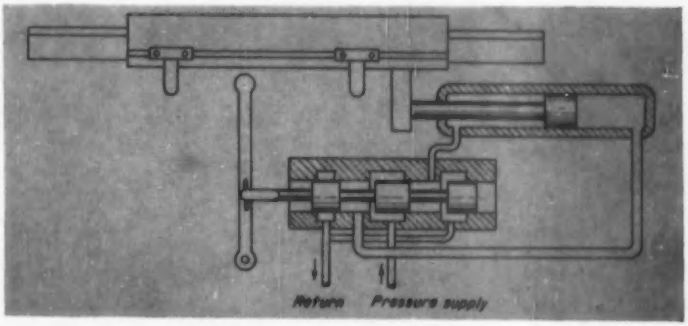
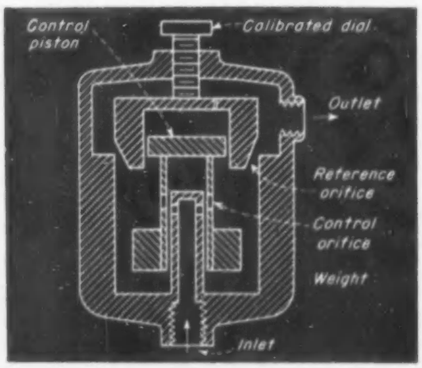
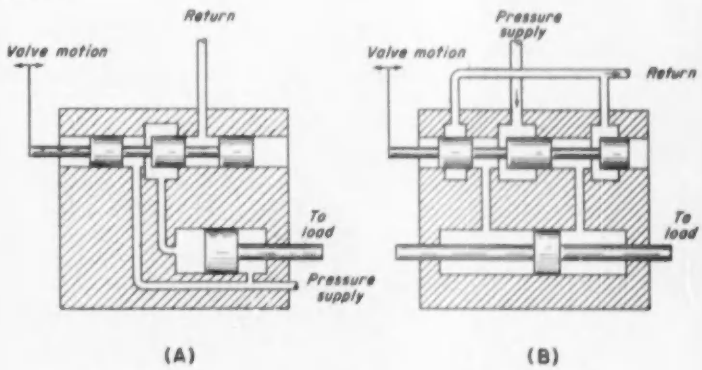


FIG. 4.



Simple valve for regulating to constant pressure from variable source. Pressure drop across reference orifice must cause a differential force on the control piston equal to piston weight.

FIG. 5.



(A) Three-way valve controlling a differential ram;
(B) Four-way valve controlling a double-acting ram.

NOMENCLATURE

A —Area, in.^{2}
C_d—discharge coefficient, dimensionless
D —minimum dimension of orifice, in.
L —average distance from inlet to metering orifice, in.
μ —absolute viscosity, lb sec/in.^{2}
P —pressure, lb/in.^{2}
Q —volume rate of flow, in.^{3}/sec
ρ —fluid density, lb sec^2/in.^{4}
T —absolute temperature, deg F
U —underlap, in.
V —average velocity of fluid through orifice, in./sec
w —port width of valve, in.
W —weight rate of flow, lb/sec
X —valve displacement, in.

SUBSCRIPTS

a —load side of valve
d —downstream (except on discharge coefficient, C_d)
e —exhaust
i —initial condition
m —motor
o —orifice
s —supply
u —upstream

SINGLE ORIFICE VALVES

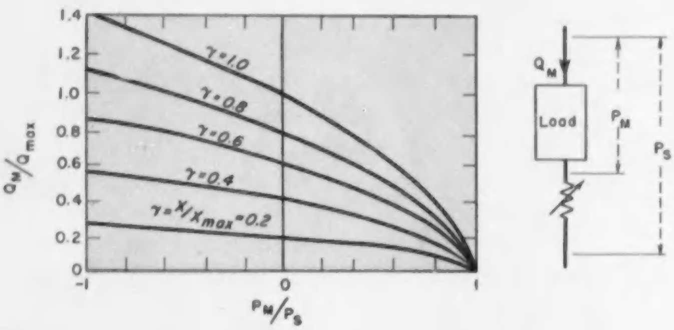
For control with one-way flow:

HYDRAULIC

Flow versus pressure characteristics are nearly parabolic. The departure from a true parabola when the valve is nearly closed is due to viscous friction at low Reynolds numbers ($\rho VD/\mu$). The flow-pressure characteristic flattens for Reynolds numbers less than 250; for higher values if the valve does not have sharp corners[1]. For larger valve openings, orifice flow conditions hold, and

$$Q = C_d A_o \sqrt{\frac{2(P_u - P_d)}{\rho}}$$

where $C_d = 0.60$ to 0.65 (approx. for sharp-cornered orifices). For other cases use experimental data.



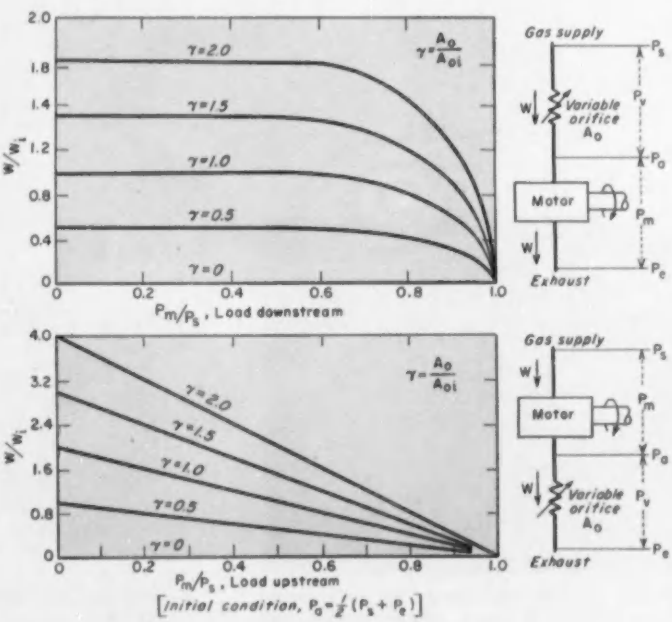
Pressure-flow characteristics for single-orifice hydraulic valve.

PNEUMATIC

For a highly compressible fluid like air, the flow-pressure characteristic is somewhat different. Unlike hydraulic, its shape depends on whether the load is upstream or downstream. The upstream load case is generally better for decelerating large-inertia loads. Orifice conditions hold throughout the range because the very low viscosity of air and practicable machining tolerances obviate Reynolds numbers as low as 250. This same low viscosity results in appreciable leakage in clearance spaces. The flow relationship for air is:

$$W = (0.53) C_d A_o \cdot \frac{P_u}{\sqrt{T_u}} \left(\frac{P_d}{P_u}\right)^{0.71} \sqrt{1 - \left(\frac{P_d}{P_u}\right)^{0.29}}$$

where $C_d = 0.8$ to 1.0



Pressure-flow characteristics for single-orifice pneumatic valve.

THREE-WAY VALVES

For bi-directional control. (See Figure 5A.)

HYDRAULIC

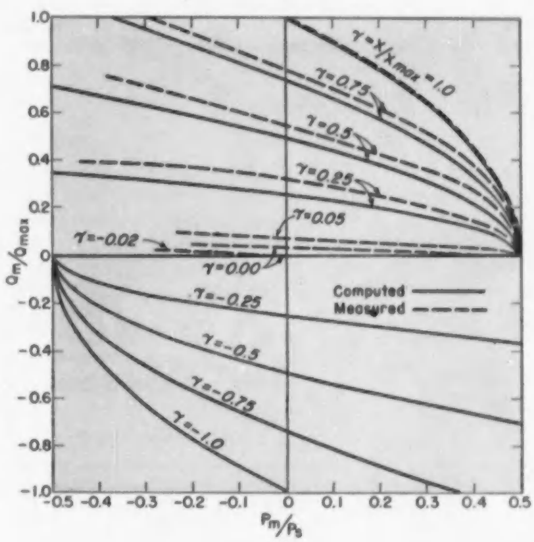
The characteristics of two single orifices are combined graphically to get the flow-pressure characteristic of the three-way valve. The computed characteristics for the closed-center valve assume perfect alignment of orifices that just close with the valve centered (no overlaps), and no Reynolds number effect at small openings. A carefully made valve was used.

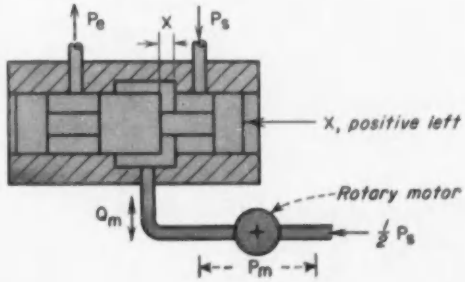
The zero-γ curve should go through zero ordinate at $P_m/P_s = 0.0$. The error is due to the measurement reference ($\gamma = 0.05$ represents 0.0005 in.), or to asymmetrical leakage in the valve. The slope in the measured zero-γ curve is due to quiescent leakage.

Theory and practice agree within measuring tolerances for the open-center (underlapped) valve because both orifices are partly open when the valve is centered. This reduces the effect of small clearances, rounded corners, and misalignments.

PNEUMATIC

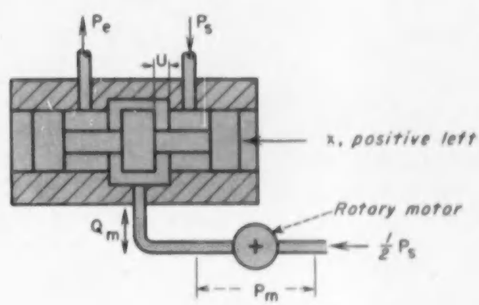
The measured and computed characteristics of even pneumatic valves agree quite closely at high pressures[2, 3]. The upstream port must generally be smaller to make load pressure with the valve centered equal half the supply pressure[3]. Characteristics shown are for negligible exhaust pressure, so flow through the exhaust orifice is critical (Mach 1.0 at the throat).

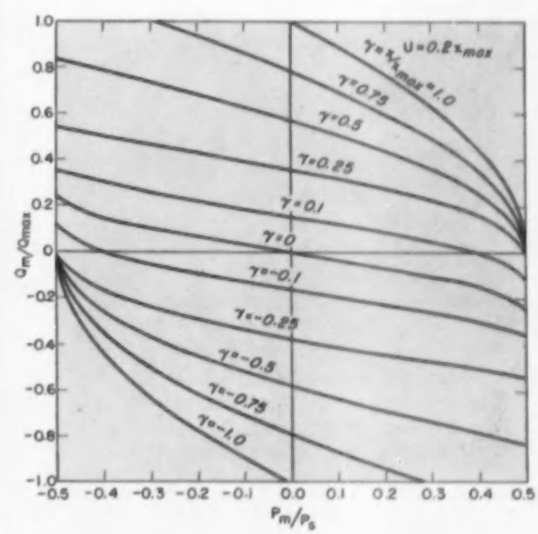


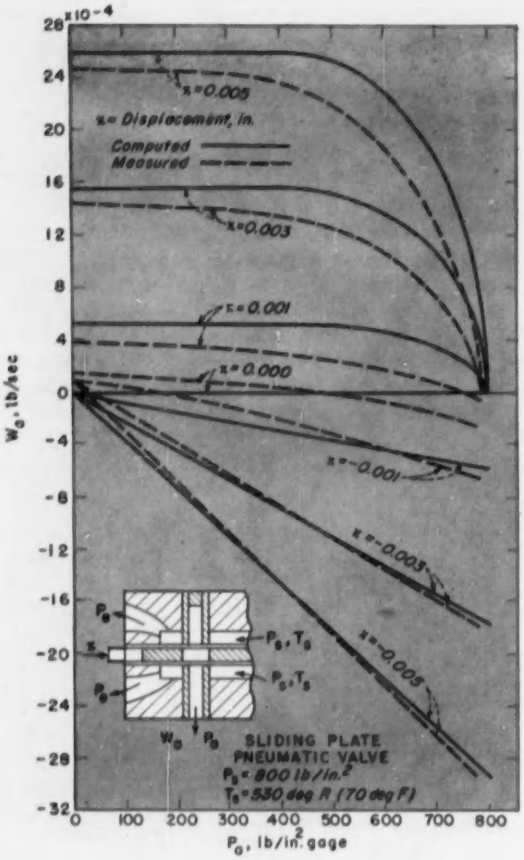


Computed and measured pressure-flow characteristics of a closed-center three-way hydraulic valve (no overlap).

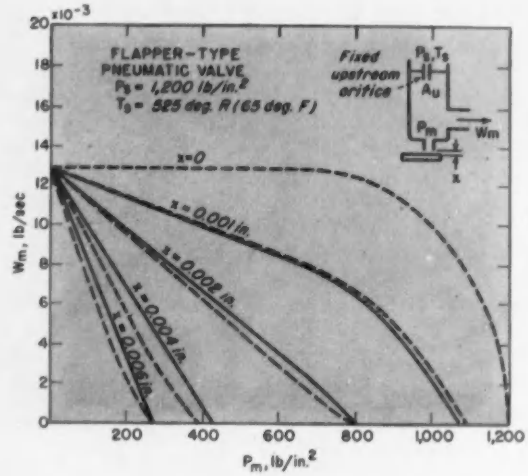
Pressure-flow characteristics of an open-center (underlap $= 0.2X_{max}$) three-way hydraulic valve.







Computed and measured pressure-flow characteristics of a sliding-plate three-way pneumatic valve (high pressure).



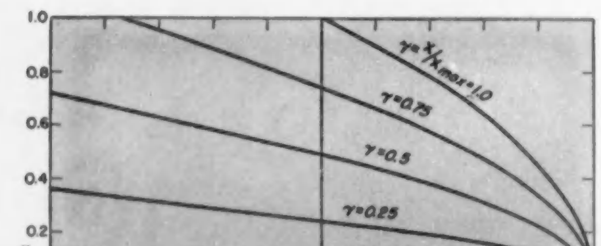
Computed and measured pressure flow characteristics of a flapper-type three-way pneumatic valve (one orifice fixed) at high pressures.

FOUR-WAY VALVES

For bi-directional control. (See Figure 5B.)

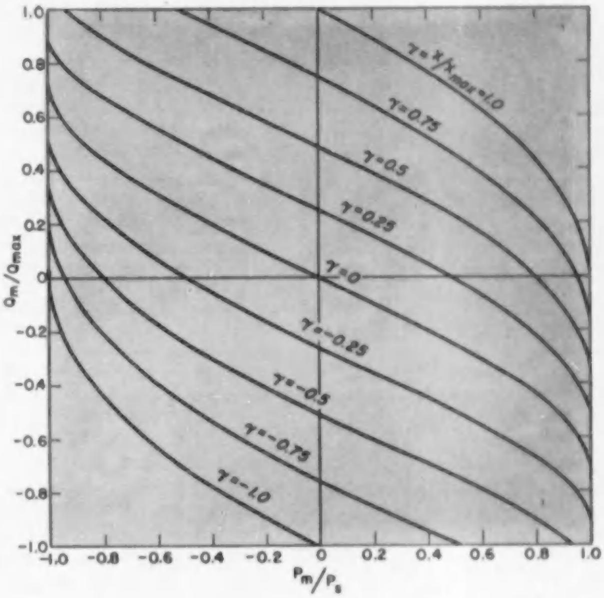
For a given supply pressure and output force, the ram area in Figure 5B need be only half that in Figure 5A. Likewise, the valve flow in 5B is only half that in 5A.

Though it is generally much more difficult to align four orifices than two, the hole-slot-ang-plug technique[4] makes it possible to get near-perfect alignment by machining metering ports when the valve is partly assembled.



Computed pressure-flow characteristics for a closed-center four-way hydraulic valve (no overlap).

Pressure-flow characteristics of hydraulic four-way valves have been discussed in detail by Blackburn[5]. The characteristics illustrated here apply only for a symmetrical load. For dynamic analysis, if the load is asymmetrical it is better to use the three-way valve characteristics that describe each direction of flow independently.



Computed pressure-flow characteristics for an open-center four-way hydraulic valve (underlap equal to maximum stroke).

FLUID-FLOW FORCES

There is a steady fluid-flow force that tends to close an open slide valve[6]. The force is proportional to the cosine of the entrance or exit angle (θ) of the jet formed by the orifice, relative to the axis of the valve motion, thus:

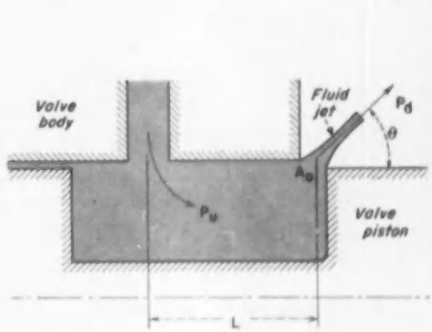
$$F_{steady} = 1.2A_o(P_u - P_d)\cos\theta$$

There is also an unsteady flow force proportional to the rate of change of flow (fluid acceleration), and in a direction depending on the flow direction[7]. If flow is in the same direction as valve motion when the valve is opening, the force opposes the motion. If in the same direction as valve motion when the valve is closing, the force aids the motion.

$$F_{unsteady} = \rho L \frac{dQ}{dt}$$

or, when the pressure drop across the valve is constant,

$$F_{unsteady} = C_d \rho L w \sqrt{\frac{2(P_u - P_d)}{\rho}}\,\frac{dX}{dt}$$



Metering orifice of typical slide valve.

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HYDRAULICS VS. PNEUMATICS FOR VALVE-CONTROLLED DRIVE

FACTOR	HYDRAULIC FLUID	COMPRESSED GAS
1. OVER-ALL SYSTEM COMPLEXITY	Pump, pressure control, sump, filter, and heat exchanger	Multi-stage compressor with interstage cooling, pressure control, filter, dryer (no return line)
2. WORKING FLUID	High quality mineral base oils with additives, water base solutions, synthetic liquids. (All expensive – some flammable)	Air, nitrogen, products of combustion
3. EFFICIENCY	Seldom over 60 per cent	Seldom over 30 per cent
4. OVER-ALL SIZE	Approximately the same for a given supply pressure	
5. EASE OF ENERGY STORAGE	Air- or spring-loaded accumulator	Simple tank
6. LUBRICATION OF MOVING PARTS	Usually good – sticking valves usually due to poor design or dirty fluid	Small amounts of grease help seals to last – air has negligible lubricating qualities
7. SUSCEPTIBILITY TO MOISTURE	Will not attack corrosion resistant materials – small amounts of water will eventually dissolve traces of acids or salts in mineral base oils and attack corrosive materials. Regular change of working fluid generally recommended at fixed intervals of time	Corrosion resistant materials recommended throughout pneumatic systems due to combination of small amounts of moisture and other contaminants in atmosphere. Small amounts of water can freeze valves and render them inoperable below 32 deg F
8. SUSCEPTIBILITY TO CONTAMINATION (VARIOUS KINDS OF DIRT)	Closely fitted valves (0.0002 in. clearance) stick very easily except when best dirt filters are used. Oil has "washing" action that dislodges particles that would adhere to walls	Less trouble than with oil. Foreign particles seem to drop out of air before it gets to valve. Little "washing" action apparent with air. Dirty combusion products are troublesome
9. EASE OF MANUFACTURE	Valves usually require great care. Precision machining usually required throughout	Same as hydraulic, but valves need more care and tight seals are difficult to attain
10. SAFETY OF OPERATION	Leakage of flammable fluids a fire hazard. High velocity jet can pierce skin and cause blood poisoning. Fluid can cause serious eye inflammations. Not explosive	Flying debris from a rupture can be very dangerous. Explosions possible when small amounts of volatile fuel such as oil are present in air – not with pure nitrogen
11. TEMPERATURE SENSITIVITY	Most hydraulic fluid viscosities change greatly with temperature changes. Unequal expansion of dissimilar materials can give serious trouble. (Some "orifices" behave as orifices only when fluid viscosity is low). If temperature is too high fluid vaporizes – if too low, it solidifies	Since viscosity of most gases is much less than that of hydraulic fluids relatively little trouble can be expected from viscosity changes. Same trouble as with hydraulic systems when dissimilar materials work together. Neither liquefaction or freezing are common
12. VALVE STROKING FORCES	Both steady and dynamic flow forces are often significant. Stiction due to dirt or lateral forces (pressure unbalanced) is common in control valves	Neither steady nor dynamic flow forces is often significant due to low fluid density. Steady flow force can cause high velocity (1,000 fps) at throat of control valve. Lateral forces very troublesome because of lack of lubrication. Stiction due to dirt seems less troublesome
13. PRESSURE RANGE	50 – 5,000 psig	5 – 3,000 psig
14. RELATIVE SPEED OF RESPONSE	Usually better than any other means of control at same output power level	Not as good as same system with hydraulic fluid; better than electric drive at same power
15. DRY FRICTION ACTING ON OUTPUT SHAFT	Can cause excessive steady errors in a position servomechanism, especially when an open-center valve is used	Steady errors in position servomechanism more serious than in some hydraulic drives. Can also cause large low frequency phase shift
16. QUIESCENT POWER DRAIN	Usually less than 10 per cent of maximum output power with a closed center valve. Up to 100 per cent with open center valve	Up to 20 per cent of maximum output power with closed center valve. Up to 100 per cent of maximum output power with open-center valve
17. ROTARY MOTORS FOR CONTINUOUS CONTROL	Many types commercially available. Some work at pressures up to 5,000 psig	Few available – none at pressures above about 100 psig

A BASIC ADVANCE IN SYSTEM SAFETY:

"FAIL-SAFE" Gets New Meaning

When a component in a control system fails, it can cause the system to revert to a safe static condition—or it can create a ruinous condition of uncontrolled runaway operation. Designers have put long and earnest effort into component reliability. But, because failure possibility can never be eliminated, efforts have been made to design systems so that a "safe" condition of control will result in the event of component failure. Despite these efforts, almost all modern control systems contain several possibilities of unsafe failure. The fact is, component reliability is no substitute for system safety.

Here is a new and startlingly simple approach to "fail-safe" system operation that goes back to the conceptual stage of system design. It applies to control systems of any type and complexity. And it is basic to the system concept: it will work no matter what engineering specialties are involved —electronic, electromechanical, hydraulic, or whatever.

Best of all, for all its invaluable protection, the new fail-safe concept calls for very few extra components in most systems. It can be applied to even the oldest existing system at very little cost.

W. G. ROWELL, Scully Signal Co., and
A. B. VAN RENNES, MIT

In the past, the term "fail-safe" has been applied to systems that remain safe when power fails. It has been associated also with "safe-start" systems, which cannot be started unless certain system conditions are met. Though it is agreed that these systems have many possibilities of unsafe failure, they have been approved by official testing laboratories on the theory that unsafe failure conditions are "inherent" in electronic circuits and physical systems.

Inherent unsafe failures in electronic equipment can be loss of emission, or open heater, plate, or cathode resistors in the case of a vacuum tube that is normally nonconducting; a grounded control grid or grid-to-cathode short in the case of a normally conducting tube. These failures can all be defined as component failures that cause to be produced at the output the effect of a normal output signal.

The truly "fail-safe" system is one in which absolutely no equipment malfunction can occur without an appropriate signal being given. This signal may warn, may shut down the equipment, or may switch in a fail-safe standby system.

The definition, however, needs some bounds. Fail-safe does not mean fail-proof: if a component fails, the fail-safe system simply indicates its inoperability and reverts to a safe condition of equilibrium. It can also switch in a substitute system, but it is not self-repairing. No system is fail-proof.

Also, a system is usually fail-safe only in the event of "normal" component failures. Every part of a system is a component, including the wiring, piping, or other signal or power links. Normal component failures include wiring shorts to ground or to adjacent wiring or components. They do not include failures like a short between two terminals purposely remote from each other, which could be caused only by some element external to the system. Fail-safe systems are not inherently tamper-proof, but some of the simpler fail-safe indicators actually are tamper-proof.

THE NEW PRINCIPLE

The new fail-safe technique is sufficiently basic to be applicable to practically all types of electronic, electrical, and mechanical systems. Its application to a monitoring system will show how it works. The technique periodically alters the normal "safe" input signal to a simulated "unsafe" signal. The result is a continuous . . . safe-unsafe-safe-unsafe. . . oscillation. The alarm, or protective device, is normally "on", and is held "off" by an alarm suppression circuit sensitive to the oscillation itself. If the normal operating signal fails (operation becomes unsafe), a continual non-oscillating "unsafe" signal results and

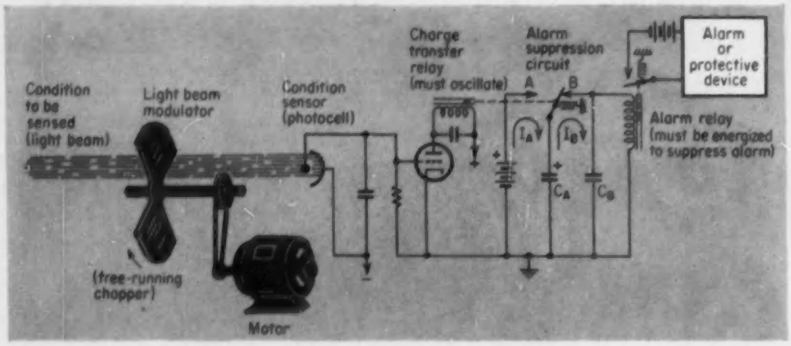
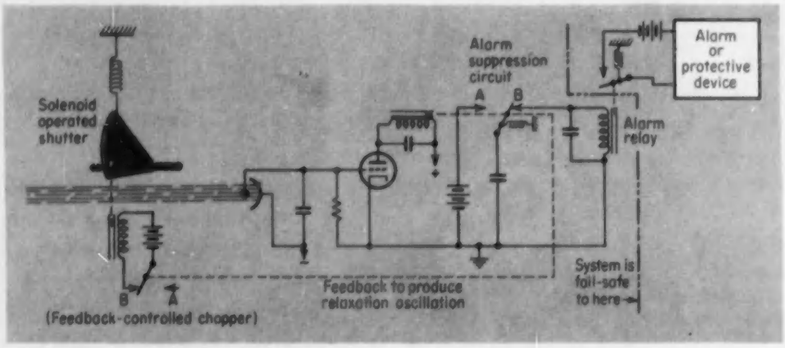


FIG. 1. Fail-safe light monitoring system.

FIG. 2. Same system as Figure 1, except oscillation is generated by feedback.



allows the alarm to sound. If the monitoring system fails, the oscillation stops and the resulting continual "safe" signal actuates the alarm.

The Scully-Rowell fail-safe technique is essentially that of continually "exercising" the monitoring system to prove its operability. The frequency of the oscillation impressed on the system is determined by the speed with which alarm must be given following failure of the condition to be sensed. The safe-unsafe oscillation period must be slightly shorter than the maximum allowable alarm lag.

Monitoring of security systems and slow-acting processes may only require one oscillation every several minutes. In the surveillance of combustion control systems and in the control of nuclear reactors, an extremely high monitoring frequency may be necessary.

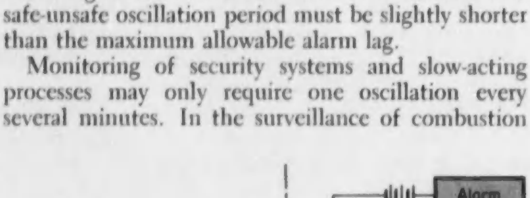


FIG. 3. Fail-safe demodulator with no mechanical oscillations. The alarm circuit relay energizes on a voltage higher than the highest source in the system.

"Unsafe" Simulation

There are several ways to modulate the "safe" operating signal to produce the required oscillation. A basic form of fail-safe monitoring equipment is shown in Figure 1. Here the condition, or signal, to be sensed is a light beam. An alarm or protective action is desired if the light beam should fail.

Failure of the light beam can be simulated by a motor-driven chopper. This periodically prevents the beam from reaching the photocell and, via the amplifier, causes the relay armature to oscillate from contact A to contact B. In position A, current I_A charges capacitor C_A. In position B, current I_B transfers the charge from the alarm suppression circuit to the alarm relay circuit. The time constant of the alarm relay circuit is slightly longer than the period of oscillation of the light beam to hold off the alarm or protective device during normal operation.

Note that the relay arm in the alarm suppression circuit must oscillate to prevent the alarm from sounding. If the relay contact (which is the non-bridging type) stops in either position A or position B, one or both of the capacitors will discharge and allow the alarm relay to close. Thus the oscillating condition must exist to suppress the alarm.

Note also that the monitoring circuit of Figure 1 is an open-loop system. The oscillation is caused

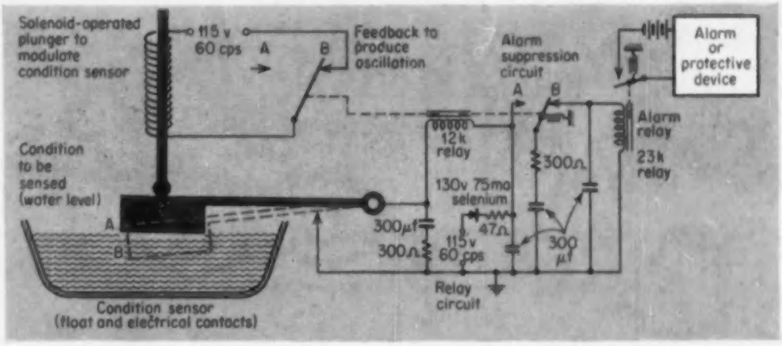


FIG. 4. Periodic depression of float by feedback tests water-level monitor. Float must rise by buoyancy. For values shown oscillation period is 6 sec.

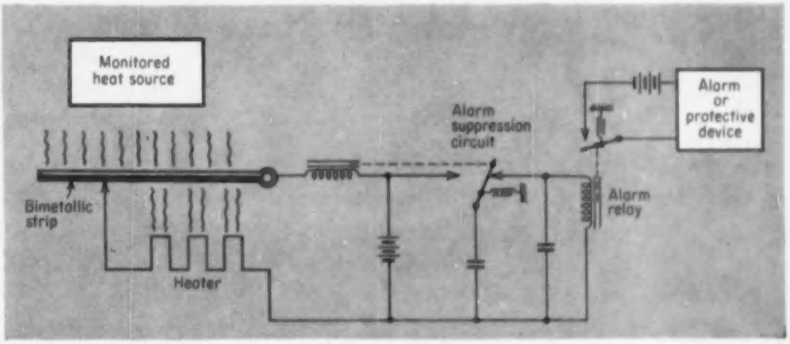


FIG. 5. A simple fail-safe temperature monitoring system.

by a free-running externally driven chopper. Feedback is not necessary to the fail-safe technique, but it can be used to generate the required oscillation within the monitoring system, as in Figure 2.

If the light source is an electric lamp (rather than, say, an oil burner flame), the lamp itself can be modulated, thus avoiding the problems of mechanical light interruption. Again, both free-running and feedback modulation of the light is possible.

In both Figures 1 and 2, the alarm suppression circuit is inherently fail-safe, provided contacts A and B on the oscillating relay are isolated from each other so a short cannot occur by normal circuit failure (i.e., without tampering). An alternate alarm suppression circuit is shown in Figure 3, where a step-up transformer is used to supply an alarm circuit relay that has a high operating voltage. No other voltage in the system is high enough to operate the alarm relay.

All of these circuits are fail-safe up to but not including the alarm circuit. If desired, the fail-safe technique can be applied to the alarm circuit and to the alarm or protective device. A special relay "contact checking" circuit has been developed for this purpose.

If the oscillating relay in the circuit of Figures 1 and 2 stops on the contact B it generally indicates loss of the monitored signal. If it stops on contact A, it indicates failure of the monitoring system. Thus, a second set of contacts on the oscillating relay can be placed in series with the alarm or protective device. This would prevent sounding the alarm or shutting down the monitored system in the case where only the monitor fails. A secondary alarm would indicate the monitor failure.

Other Fail-safe Examples

Getting away from pure electronics, failures in steam-boiler water-level monitoring systems have been responsible for more than 38 per cent of industrial boiler explosions in recent years (*Power*, McGraw-Hill Publishing Co., September 1953). Figure 4 shows how a water-level control system can be made fail-safe. Figure 5 illustrates a simple temperature monitoring circuit that has been made fail-safe by modulating the bimetalic sensing element.

In general, each application of this fail-safe technique represents a specific design engineering problem. For example, frequency of the monitoring oscillation must not be near that of the power line or any other frequency common to the system. Monitoring frequencies that could be produced by amplifier "motorboating" (low-frequency oscillations), in the case of certain filter component failures, should be avoided. Where a final alarm relay is used, care must be taken that normal component failures or insulation breakdowns cannot cause the relay to be energized directly from a power source.

Again, no system can be made fail-proof. But they can be made fail-safe.

U.S. and foreign patents are pending and issued on the techniques described in this article.

NONLINEARITY IN CONTROL SYSTEMS

PART II—METHODS OF ANALYSIS AND SYNTHESIS

Techniques for analyzing nonlinear control systems guide the designer toward more efficient and effective synthesis—that is, toward the selection of efficient and economical measures for improving system performance. This article discusses several of these techniques. Two of them are illustrated by the example of a contactor servo problem.

R. J. KOCHENBURGER
University of Connecticut

Familiarity with methods of analysis increases the designer's ability to cope with nonlinearities in feedback control systems. Before the development of useful methods of analysis and synthesis a system designer often avoided or ignored these nonlinear effects—usually because they made the analysis too difficult. Therefore, the designer often missed opportunities for using these nonlinearities to improve the system's performance. A knowledge of the following methods aids the designer toward fuller realization of a system's capabilities.

DIRECT SYSTEM TESTS

In the early years of control system development the only analytical means available to the designer was a test of the system itself. Thus, a system test was run for each trial adjustment of the design constants. Synthesis could be achieved, but only indirectly: by a number of trial and error adjustments. In some systems the numerous permutations and combinations of such adjustments made synthesis impractical, and the designer found he was "working in the dark".

For a variety of reasons a direct test may not be feasible. Perhaps the control system is still in the design stage. Perhaps the device being designed is of the "one shot" type, such as a guided missile, making repeated trial and error costly and hazardous. Or perhaps an industrial process already in operation cannot be interrupted for tests without expensive curtailment of production. When problems such as these exist analog computer tests help determine optimum design constants.

ANALOG COMPUTER TESTS

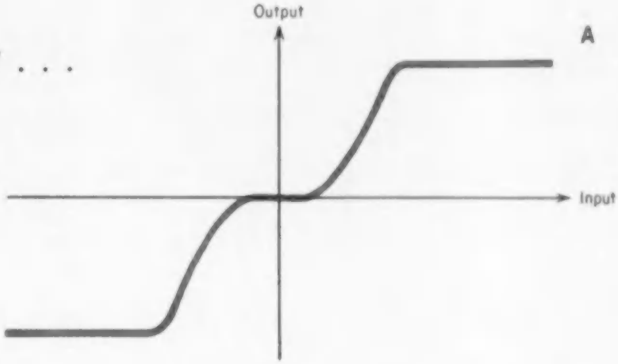
A system's analog is simply a model that represents the physical quantities of the system in a form that is convenient and economical in both construction and test procedure. The analog obeys the same mathematical equations as those which describe the dynamics of the actual system. For example, hydraulic flow tables have been used successfully as analogs of nonlinear systems.

The most familiar form of analog, and possibly the most versatile, is the electronic analog computer[1]. Here, electrical voltages represent the physical quantities. The computer performs the familiar linear operations of addition, subtraction, integration, differentiation, introduction of time constant, etc. Likewise, the electronic analog computer aids the study of nonlinear systems.

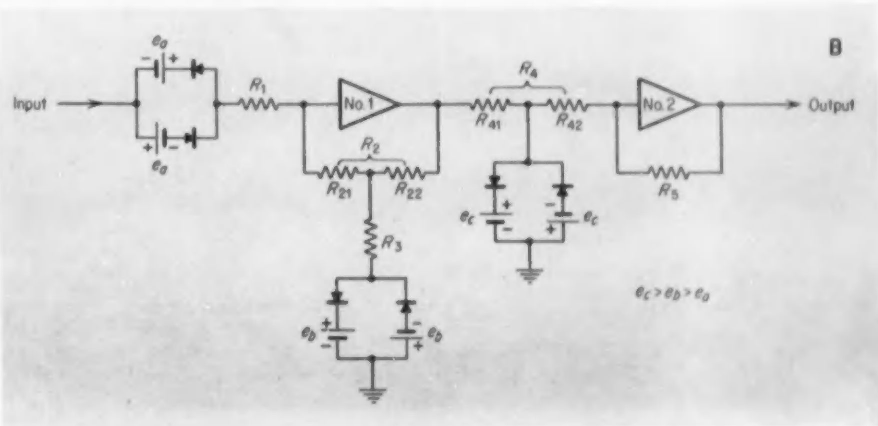
Figure 1A shows an example of nonlinear analog. A nonlinear relationship (which might conceivably occur in practice) is between the input and output of a system component. This relationship is characterized by an "inactive zone", by an initially increasing slope, and then by a saturation effect. The circuit in Figure 1B shows one way to represent this

A NONLINEARITY . . .

FIG. 1. The curve in Figure 1A represents a nonlinearity with a dead zone, a rising slope, and a saturation effect. The circuit of Figure 1B simulates this curve on an electronic analog computer.



. . . AND IT'S ANALOG



8 PRACTICAL CONTROL TIPS BASED ON NONLINEAR ANALYSIS

1. Response damping can be effectively improved by the introduction of coulomb friction at the output shaft of otherwise linear servomechanisms, provided that the input signal is stationary, consists of simple step changes, or varies about a constant mean value. Whenever the input command varies unidirectionally, the damping effects of coulomb friction are lost, although its detrimental contribution to system error still exists.
2. In contactor systems, some inactive zone is always necessary to avoid self-sustained oscillations.
3. Any nonreversible input-output relationship in a system component (magnetic or dielectric hysteresis, backlash or free play, contactor hysteresis or detent action, etc.) detrimentally affects stability, and can cause an otherwise nonoscillating system to exhibit self-sustained oscillations.
4. Contactor time delays in contactor control systems detrimentally affect stability and may cause self-sustained oscillations.
5. Adequate servo motor damping or braking in the neutral correction interval improves the overall operation of contactor systems.
6. Describing-function analysis shows the effects of saturation and simple limiting to be equivalent to a reduction in gain at high operating frequencies. This is particularly significant in systems that employ phase lag networks to improve system operation. Here the systems become less stable when the gain is reduced.
7. Limiting the output velocity of a servo improves response damping in face of large disturbances and introduces a beneficial phase lead.
8. Limiting the acceleration (as might be done for protective purposes) introduces a phase lag. Thus, system stability may be adversely affected.

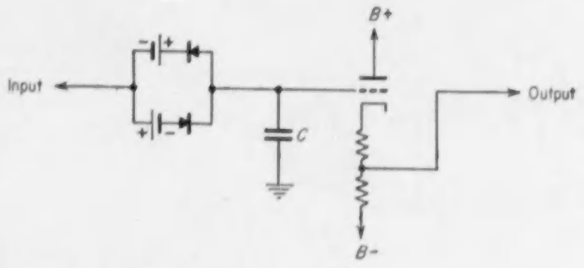


FIG. 2. This electrical circuit simulates simple backlash on a computer.

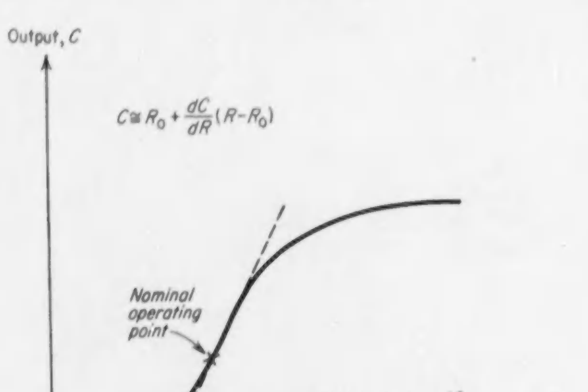


FIG. 3. A slight nonlinearity can be represented by the curve's slope about the operating point. But a large variation in the operating point may negate the method.

nonlinear characteristic on the computer. It operates as follows:

▶ the bias voltages e_a and associated rectifiers provide the inactive zone effect

▶ as the input voltage increases beyond the inactive zone the output voltage first rises at a moderate rate because of the moderate gain of amplifier #1 (determined by the ratio of R_2 to R_1)

▶ as the input increases further, one of the rectifiers associated with e_b becomes conducting and reduces the amount of negative feedback in amplifier #1. The reduced feedback increases amplifier gain and thus increases the curve's slope

▶ and, as the input voltage increases still further, one of the rectifiers associated with e_c "cuts in" and limits the output voltage of amplifier #2 to simulate the saturation portion of the curve.

If the rectifiers in this circuit were truly ideal, a plot of the output-input relationship reproduced by the circuit would consist of straight-line segments that approximate the true curve. But because the rectifiers used in practice will not possess absolutely sharp cutoff characteristics there will be a "Luring" of the curve. Hence, by proper design and selection of constants and components the actual nonlinear relationship can be reproduced to a reasonably faithful degree. More exact representation is possible by the addition of more rectifier elements and more critical adjustment of parameters.

Many important nonlinearities, such as hysteresis and backlash, depend upon past history. These effects can also be reproduced by analog computer circuits. The circuit in Figure 2 simulates mechanical backlash.

Analog computer schemes, such as those described above, represent typical nonlinear effects appearing in control systems. The direct testing procedure can therefore be transferred from the actual system to an electronic model. Thus, many practical objections associated with direct system testing may be avoided. However, the fact still remains that analog tests, as well as actual system tests, perform a basically analytic service. With these two methods synthesis is still an awkward trial and error procedure. But analog computer studies can be more useful if they are correlated with mathematical studies based on one of the following methods of analysis.

TRANSIENT RESPONSE APPROACH

When a nonlinearity is slight (within a given range of operation) its effect may be treated as though it were linear[2]. Figure 3 shows a nonlinear characteristic that may be approximated by a linear relationship for small deviations from a nominal operating value. The curve's "linear" slope describes performance, but it should be noted that this parameter may vary as the operating point changes. Given such an approximate linearization procedure, conventional transient analysis techniques or more sophisticated versions, such as the root locus method[3], may be applied.

When the nonlinear effect is more marked or when the variables deviate so much from the operating point as to preclude the above method, then system transient analysis becomes more difficult. However, classical methods of numerical or graphical integration may be employed. Highly developed in the field of fluid transient analysis, these methods also apply to feedback control problems.

Piece-wise solution of the system's differential equations apply particularly to the analysis of control systems that use contactors or that are characterized by coulomb friction. Here the nonlinear parameter stays constant during a given interval of the correction process and then changes abruptly to another constant value as the correction conditions change. The system is linear during each interval. The classical transient analysis approach requires that the equations be expressed for each new interval, with the initial conditions from the previous interval inserted in the new equation.

The basic principle of piece-wise solution was proposed by Hazen in 1934[4], and since has been ex-

tended by others. Hazen considered relatively simple systems and managed to derive analytic relations based upon the requirement that the final conditions be matched with the new initial conditions. From this he determined whether a given system subjected to a disturbance would settle down or would exhibit steady-state oscillations. In the latter situation the frequency and amplitude of the oscillations could be found. Subsequent improvements of this approach[5] led to various graphical procedures that simplify the analytic process.

PHASE-PLANE METHOD OF ANALYSIS

Another version of the transient response approach is the phase-plane method. Two advantages of this method stand out: it gives a graphical portrayal of the response which leads to a physical picture of what is occurring, and it is especially adaptable to system synthesis. This method was proposed some time ago with respect to analysis of contactor servomechanisms[6,7].

The phase-plane method appears particularly useful when dealing with gross nonlinearities. It is limited, however, in that the basic method is restricted to systems describable by second-order differential equations. But fairly elaborate techniques extend its use to higher-order systems, such as the phase-space method for third-order systems.

Fortunately, because many complicated systems can be approximated as simple second-order systems, the phase-plane method serves to advantage even though it may not constitute a completely accurate portrayal of performance.

A PRACTICAL EXAMPLE–

The construction of trajectories (Figure 6) and their development into a phase-plane diagram (Figure 7) follow this introductory analysis.

An example of a contactor servomechanism (Figure 4) best describes the phase-plane method. Here, the system error equals

$$E = R - C, \text{ where}$$

E is the error voltage
R is the voltage developed across the input position-sensing potentiometer due to input position
C is the voltage developed across the output position-sensing potentiometer due to output position

The error voltage operates the polarized relay that controls the direction of rotation of the reversible motor. Whenever system error exceeds certain limits correction is applied. And an error within these limits results in a neutral interval (no correction).

Suppose the input signal R is a step-change. Then the response of error E and output C is of interest. In the simplest case only the lag caused by motor and load inertia need be considered. Further, assume balanced operation, so that

- with neutral correction—motor velocity C' $\left(\frac{dC}{dt}\right)$ approaches zero
- with positive correction—motor velocity C' approaches plus R deg/sec
- with negative correction—motor velocity C' approaches minus R deg/sec

The symbol R therefore represents the servo motor's *runaway velocity*.

With the motor at standstill and correction suddenly applied, the motor velocity approaches plus R, varying with time in the manner shown in Figure 5A. This variation follows the equation

$$C' = R\,(1 - \epsilon^{-t/T_+})$$

Here, T_+ is defined as the time constant associated with positive correction. Similarly, there exists a time constant T_- associated with negative correction. For symmetrical operation both T_+ and T_- would be identical. In addition, neutral correction can be applied with the motor initially rotating at

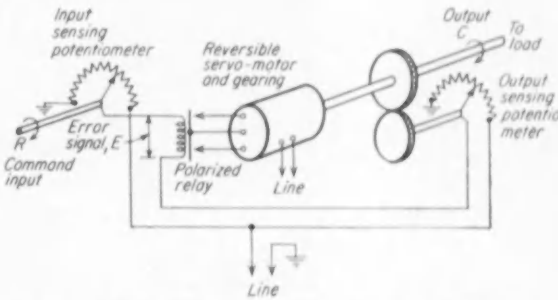


FIG. 4. This circuit illustrates an elementary contactor servo system, analyzed in some detail in the text by both the phase-plane and describing-function methods of nonlinear analysis.

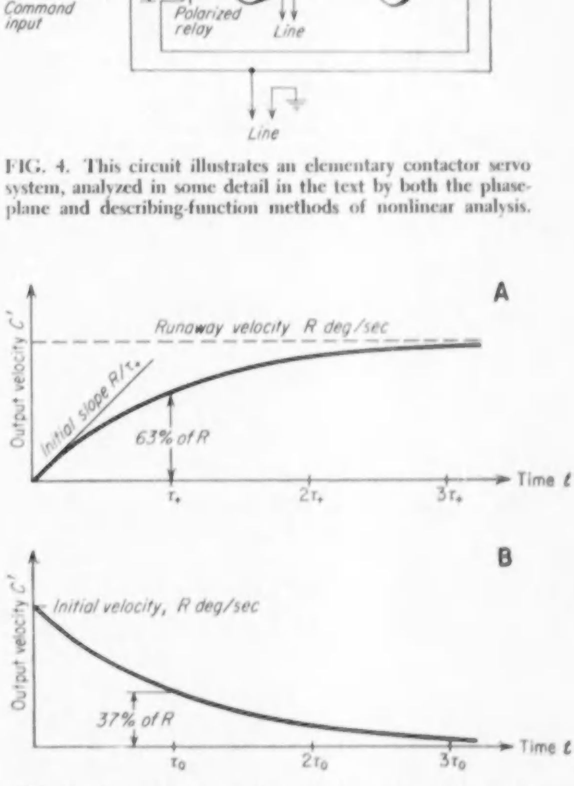


FIG. 5. Figure 5A shows the output variation for positive correction in the contactor servo, with the motor initially at standstill. Figure 5B shows the output variation for neutral correction with the motor at some initial positive velocity. Both curves vary exponentially with time.

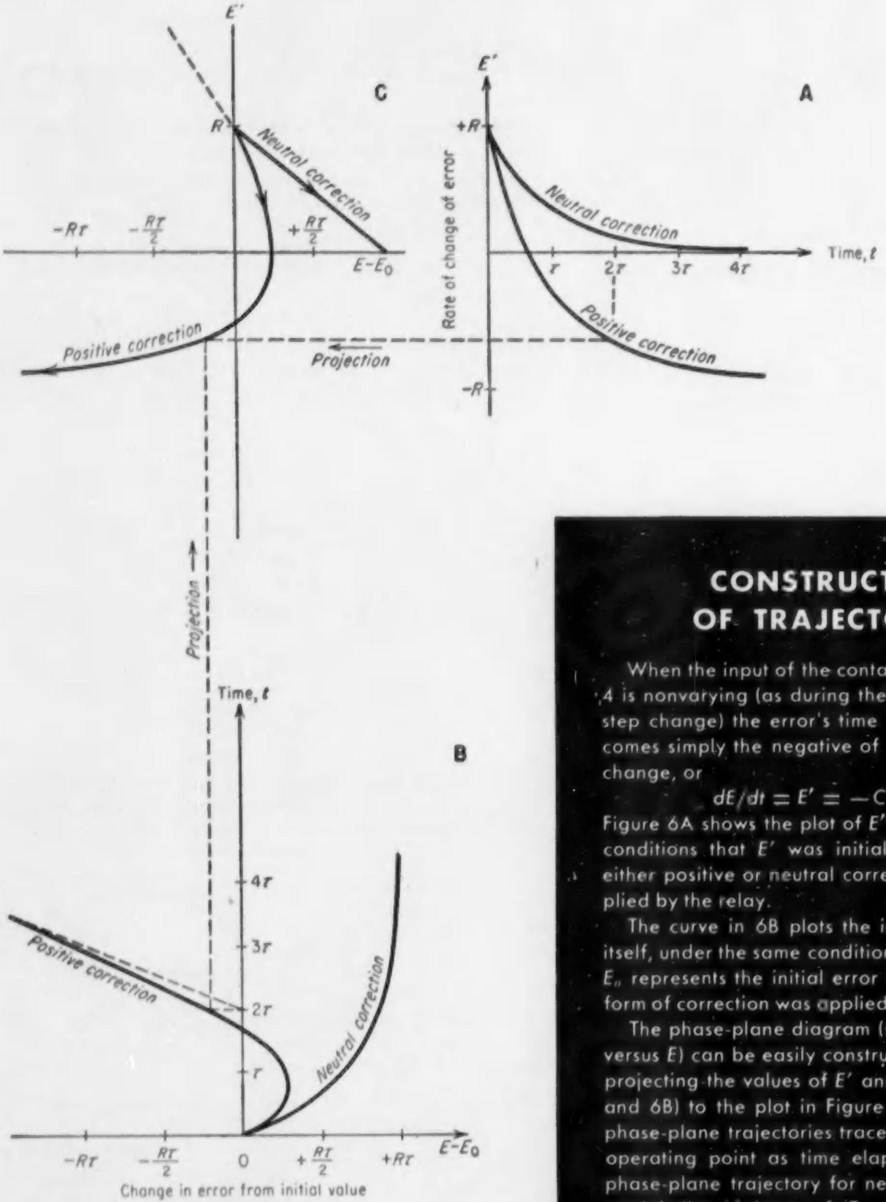


FIGURE 6

CONSTRUCTION OF TRAJECTORIES

When the input of the contactor servo of Figure 4 is nonvarying (as during the period following a step change) the error's time rate of change becomes simply the negative of the output's rate of change, or

$$dE/dt = E' = -C'$$

Figure 6A shows the plot of E' versus time, for the conditions that E' was initially plus R and that either positive or neutral correction has been applied by the relay.

The curve in 6B plots the increment in error E itself, under the same conditions. Here, the symbol E_0 represents the initial error at the time the new form of correction was applied.

The phase-plane diagram (simply the plot of E' versus E) can be easily constructed by graphically projecting the values of E' and $E\text{-}E_0$ (shown in 6A and 6B) to the plot in Figure 6C. Arrows on the phase-plane trajectories trace the progress of the operating point as time elapses. Note that the phase-plane trajectory for neutral correction is a straight line of slope $-1/T$.

The phase-plane trajectories on this page refer to specific conditions. Other trajectories, for other initial conditions, would be identical in shape and would differ only in their position along the horizontal axis. The trajectories for negative correction are similar to those for positive correction except for an inversion of both axes. The neutral-correction trajectory lies below the axis for negative initial values of E, but still remains a straight line of slope $-1/T$. It is then drawn with the arrow pointing upward.

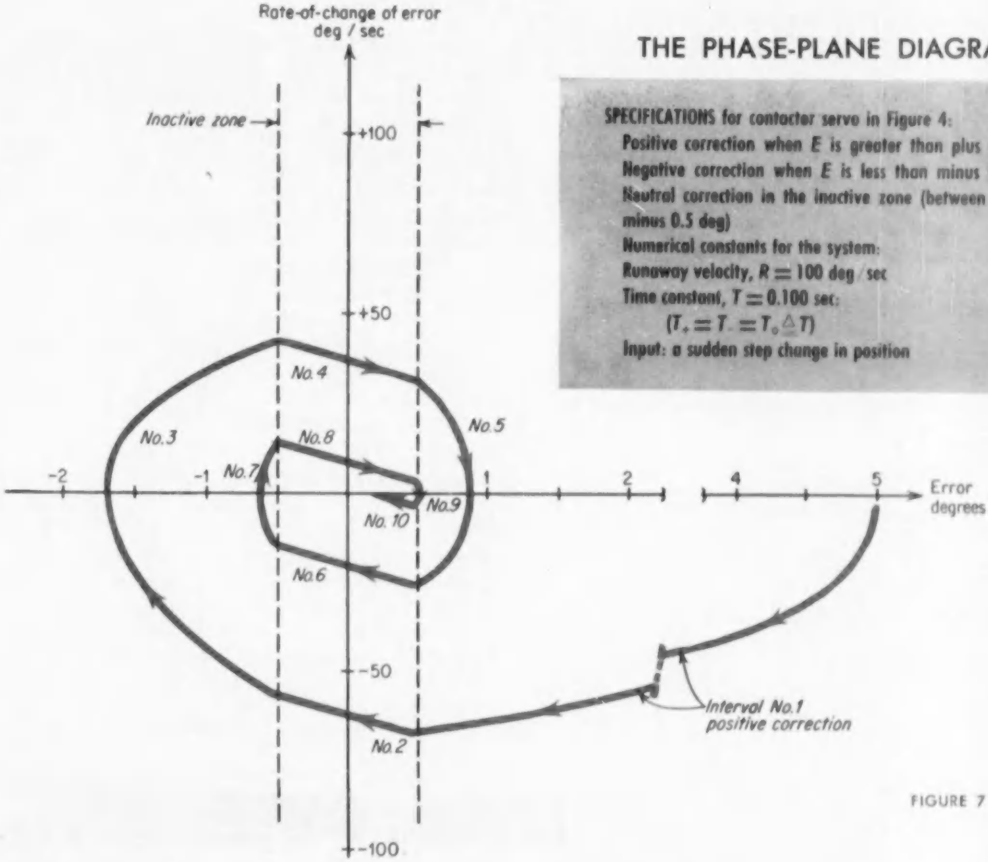


FIGURE 7

THE PHASE-PLANE DIAGRAM

SPECIFICATIONS for contactor servo in Figure 4:

Positive correction when E is greater than plus 0.5 deg

Negative correction when E is less than minus 0.5 deg

Neutral correction in the inactive zone (between plus or minus 0.5 deg)

Numerical constants for the system:

Runaway velocity, $R = 100$ deg/sec

Time constant, $T = 0.100$ sec:

$(T_+ = T_- = T_0 \triangleq T)$

Input: a sudden step change in position

WHAT'S HAPPENING IN THE SYSTEM

INTERVAL 1: The initial error E of plus 5 deg applies immediate positive correction. The initial rate of change of error (E') is zero. Hence, the trajectory starts at the point $E = 5$, $E' = 0$. The positive trajectory curve follows that shown in Figure 6A, but it is translated horizontally to meet the initial conditions (the specified starting point). This trajectory ends when E becomes plus 0.5 deg or where the neutral correction interval starts.

INTERVAL 2: This neutral-correction trajectory starts where the previous trajectory ended. The neutral trajectory is a straight line of slope $-1/T = -10$ deg/sec per deg. This trajectory ends at the other end of the inactive zone, where E becomes minus 0.5 deg. Then negative correction starts.

INTERVAL 3: The negative-correction trajectory is obtained by inverting both coordinate directions associated with positive correction of Figure 6C. Then it must be translated horizontally until it passes through the operating point that corresponds to the end of the preceding interval. A maximum undershoot of minus 1.7 deg occurs and then the interval ends when E again becomes minus 0.5 deg and the inactive zone is entered.

INTERVAL 4: This neutral-correction interval ends when E becomes plus 0.5 deg.

INTERVAL 5: The second positive-correction interval follows an identical trajectory curve as does Interval 1, except for the horizontal translation because of the different conditions at the start of this new interval. A peak overshoot of plus 0.9 deg occurs, and the interval ends when E again equals plus 0.5 deg.

INTERVAL 6: This is another neutral correction interval.

INTERVAL 7: A second negative-interval occurs, with a peak undershoot of minus 0.61 deg.

INTERVAL 8: Another neutral-correction interval.

INTERVAL 9: A third positive-correction interval occurs (of relatively short duration), with a second peak overshoot of 0.56 deg.

INTERVAL 10: This is the final neutral correction interval, with the end approached as a limit (mathematically, when time is infinite). The final error approaches plus 0.17 deg. The error remains in the inactive zone until another disturbance forces the error to exceed 0.5 deg.

SUMMARY: The servo, subjected to an initial disturbance of 5 deg, requires three positive-correction intervals and two negative-correction intervals. The response has an oscillatory tendency but is stable. If additional factors or response lags had been present, unstable response could have resulted.

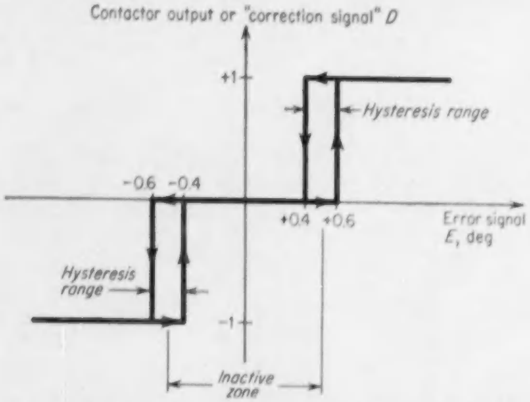


FIG. 8. When the contactor servo of Figure 4 includes hysteresis as well as dead zone, these effects must be accounted for in the analysis. Figures 9 to 12 carry through the describing-function method of analysis for this contactor servo.

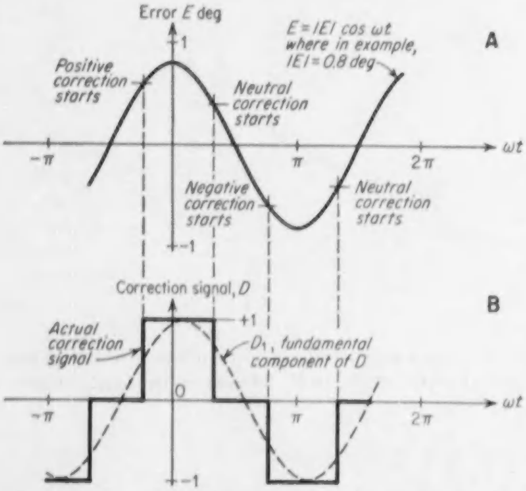


FIG. 9. Figure 9A indicates the start of the various correction intervals for the conditions shown in Figure 8. The input signal is a sine wave. The correction signal in 9B results in a rectangular wave, its approximating sine wave (as determined by a Fourier series analysis) shown by a broken curve.

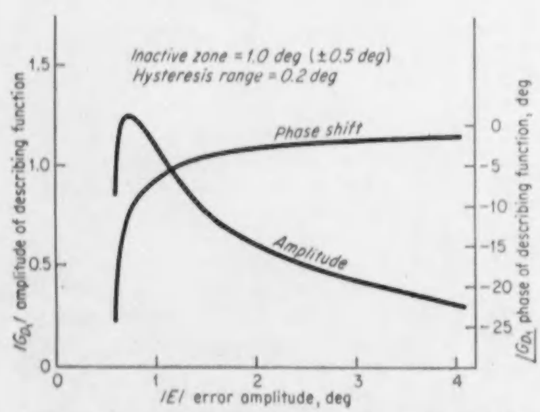


FIG. 10. The amplitude and phase shift characteristics for the contactor servo derive from the ratio of the input signal amplitude to the approximating sine wave amplitude of the distorted output. Describing function is amplitude-dependent.

its runaway value R. The speed then approaches zero, varying with time as shown in Figure 5B. This variation follows the equation

$$C = Re^{-t/T_o}$$

where T_o is defined as the time constant associated with neutral correction, and is not necessarily identical with T_+ and T_-. T_o will usually be greater, unless the servo applies braking action to the motor during neutral correction periods. Such a braking action is desirable and promotes system stability, and we assume that it is used in the present example. Hence, $T_+ = T_- = T_o \triangleq T$, simply the time constant of the motor.

Error Variation With Time

In many instances a designer requires only a phase-plane plot of the form of Figure 7. But sometimes a plot of error variation with time is desired. To get the elapsed time for any given interval the first step is to plot the error (E) versus the reciprocal of the error rate ($1/E'$). Then the following applies:

$$\int_{t_1}^{t_2} \frac{dE}{E'} = \int_{t_1}^{t_2} \frac{dE}{\left(\frac{dE}{dt}\right)} = \int_{t_1}^{t_2} dt = t_2 - t_1$$

and elapsed time equals the area under the $1/E'$ curve as plotted between the initial and final values.

Interpretaton of the Phase-plane Plot

Oscillation damping depends primarily on the reduction in E' that occurs while the system is in the inactive zone. Thus, damping may be improved by:

▶ making the inactive zone larger, but at the expense of static accuracy

▶ having a small time constant during neutral correction periods. Small time constants give a steep trajectory slope (slope $= -1/T_o$) during the neutral period. Therefore, dynamic braking, which reduces this time constant, is desirable here.

The contactor servomechanism considered here serves as a relatively simple example of the phase-plane method of analysis. Even with additional complications, such as time delay, contactor hysteresis, or coulomb friction, phase-plane plots can still be obtained. Furthermore, other types of nonlinear systems can be studied by this method. Their plots, of course, result in differently-shaped trajectories.

Limitations of the Phase-plane Method

This method of analysis is of great value to the system designer because of the clear graphical portrayal of the system's response. However, practical limitations do exist:

▶ only systems describable by a second-order differential equation (or reasonably approximated as such) can be represented by the phase-plane plot. In the

example given this method could not have been used with an additional inherent lag or with a lag deliberately introduced by a compensating network

▶ step- and ramp-change inputs are the only input disturbances that can be considered without greatly complicating the phase-plane analysis.

DESCRIBING-FUNCTION METHOD

The describing-function method of analysis depends on the steady-state response of the system to sinusoidal disturbances—rather than the transient response as for the methods discussed previously. This new method permits the same simplifications and ease of synthesis for nonlinear systems as does the frequency-response method for linear systems. And, as in linear systems, approximate predictions can be made about the nature of the transient response of the system once its sinusoidal response is known.

By the describing-function approach a nonlinear element is replaced with an equivalent element that approximately represents it for a given operating condition. This equivalent linear element affects the fundamental-harmonic component of the signal in the same manner as the nonlinear element being represented.

Describing Functions, with Hysteresis

Suppose the contactor servo of Figure 4 now includes the hysteresis shown in Figure 8. This hysteresis means that the relay used in the control circuit will require a lower error signal to open it (once it is closed) than was required to close it initially. This is typical of most practical contactors. Figure 8 indicates response of relay position to an error signal. Now, both the hysteresis range and the inactive zone must be considered in the system analysis.

The describing-function method assumes that the input to the nonlinear element (the contactor in this case) is sinusoidal. Figure 9 shows the effect of a sinusoidal error signal on contactor operation. Figure 9A represents the sinusoidal variation of error and shows the four instants when the inactive zone boundaries are crossed.

▶ With E increasing:

- negative correction ends when E becomes minus 0.4 deg
- positive correction starts when E becomes plus 0.6 deg.

▶ With E decreasing:

- positive correction ends when E becomes plus 0.4 deg
- negative correction starts when E becomes minus 0.6 deg.

If the amplitude of the sinusoidal error signal is less than 0.6 deg no correction is initiated. When the amplitude exceeds this value a correction pattern results, as is shown in Figure 9B. Here, the ordinate represents the contactor output or "correction signal", D. D equal to plus 1 indicates positive correction, D equal to zero indicates no correction, and D equal to minus 1 indicates negative correction. The correction signal shown in Figure 9B is therefore a rectangular wave.

The major assumption of the describing-function method is that the distorted nonsinusoidal output of the nonlinear element can simply be approximated by its fundamental-harmonic component. Since most control systems act as low-pass filters that attenuate high frequencies, the higher harmonics produced by the nonlinear element are relatively insignificant in the output.

To apply this assumption to the example, the fundamental harmonic component, D_1, of the rectangular wave, D, must be determined. This may be done by a Fourier series analysis. The resulting fundamental component of the output is shown by the broken-line curve in Figure 9B.

The describing function, analogous to the transfer function of a linear component, is the ratio of the output to input. In the transfer function its ratio varies with frequency, but in the describing function the ratio varies with the magnitude of the error signal. By assuming different amplitudes of error signal E, the corresponding fundamental component of the correction signal D_1 may be computed. Thus, the describing function is the ratio of D_1 to E.

$$\text{or describing function} = G_D = \frac{D_1}{E}$$

G_D has a magnitude $|G_D|$ which is simply the magnitude ratio of D_1 to E. However, in many instances (such as the example here) D_1 will lag E. Hence the describing function also has a phase angle $\angle G_D$ associated with it.

Figure 10 plots the describing function of the contactor characteristics shown in Figure 8. Note that the describing function varies, not with frequency, but with error signal amplitude. The hysteresis effect introduces maximum phase lag at low error amplitudes. When these amplitudes fall below 0.6 deg, correction suddenly ceases and the magnitude of the describing function suddenly drops from a finite value to zero.

Open-loop Transfer Function

Figure 11 shows the block diagram of the contactor control system being considered. It consists of two cascaded blocks:

▶ G_D represents the describing function of the contactor. It is a function of error amplitude and independent of frequency.

▶ G represents the transfer function of the servo motor's linear response to contactor correction signals. It is a function of frequency and independent of error amplitude; it equals

$$\frac{R}{j\omega\,(1 + 0.1j\omega)}.$$

The transfer function around the open loop is

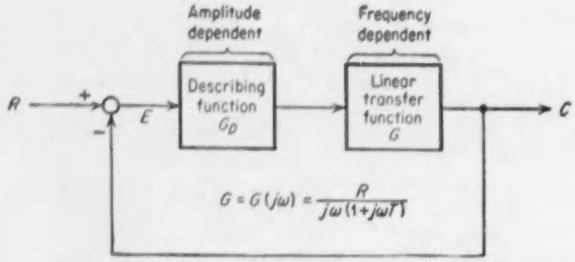


FIG. 11. The block diagram of the contactor servo used in the example separates the system into two major functions: the nonlinear amplitude-dependent describing function, and the linear frequency-dependent transfer function.

simply $-GG_D$, where the minus sign results from the system's negative feedback. Unstable oscillatory operation occurs when the magnitude of this transfer function is greater than unity and the phase shift equals 360 deg. (This is a simplified version of the Nyquist stability criteria applicable to elementary systems such as the one used in this example.) In other words, the condition for stability is simply that

$$|GG_D| > 1 \text{ when } \angle -GG_D = 360 \text{ deg}$$

If $-G_D^{-1}$ represents the negative reciprocal of the describing function, the above may be written as $|G|>|-G_D^{-1}|$ for stability, when $G = (360 + -G_D^{-1})$ deg $= \angle -G_D^{-1}$ deg.

The above relationships permit a graphical determination of system stability. A polar locus is drawn for G as G varies with frequency $\omega = 2\pi f$. Figure 12 shows such loci for two different values of the runaway velocity R. Superimposed on this same polar plot is the negative reciprocal of the describing function of Figure 10. The points on this locus correspond to various error signal amplitudes E.

The stability conditions prescribed above mean that where the $-G_D^{-1}$ locus is to left of the G locus, the operation is stable. Where the $-G_D^{-1}$ locus is to the right the operation is unstable.

Analyzing the Contactor Servo by Describing-function Method

As shown in Figure 12 for a runaway velocity of 100 deg/sec, the stability conditions are met when the amplitude of E is greater than 0.62 deg. Oscillations above this amplitude consequently decrease with time after removal of the outside disturbance. When the error amplitude is greater than the 0.6 deg cutoff value but less than 0.62 deg, unstable operation results. Oscillations in this amplitude range therefore increase with time.

Physical Interpretation

Disturbances sufficient to cause transient errors greater than 0.6 deg (hence those that initiate contactor operation) result in oscillations that decrease in amplitude if they exceed 0.62 deg and increase in amplitude if less than 0.62 deg. In any case, oscillations of amplitude 0.62 deg will eventually result. That is to say, the intersection of the two loci indicates operation with self-sustained oscillations of a fixed amplitude. In this example, the steady-state error amplitude is 0.62 deg and the frequency (corresponding to the location of the intersection of the two loci) is about 32 rad/sec or 5.1 cps.

System Improved Through Synthesis

The final operation is stable in the sense that the oscillations are of fixed and relatively small amplitude. But in many instances such self-sustained oscillations might not be desirable. They can be eliminated by reducing the runaway velocity to a lower value, say 25 deg/sec. This reduces the magnitude of the transfer function G by a factor of four. Figure 12 also shows this revised polar locus. Now, the new locus does not intersect the describing function

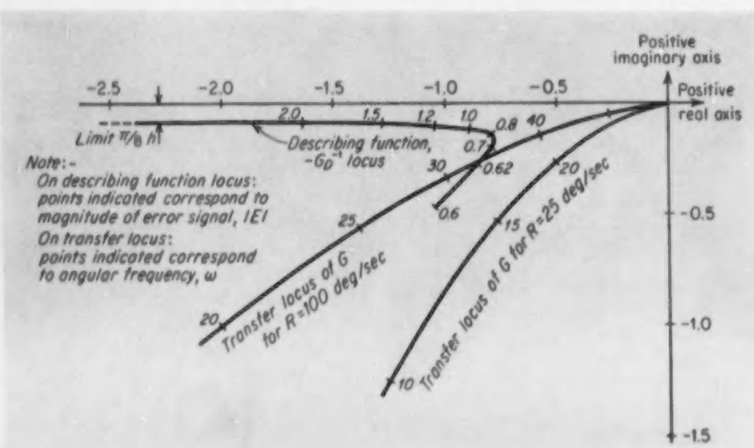


FIG. 12. Stability of a nonlinear system can be determined by the relation of the polar plots of the describing function and transfer to each other. When the negative reciprocal plot of the describing function is to the left of the transfer function plot the system is stable. Stability occurs with the G locus for R equals 25 deg/sec. But when R equals 100 deg/sec the G locus intersects the $-G_D^{-1}$ locus and oscillations occur for certain magnitudes of error. In this example, the oscillations settle to a magnitude of 0.62 deg.

locus at any point and hence no self-sustained oscillations result. The further away the two loci are from each other the greater, roughly, is system stability. One might guess from previous experience with such plots that in the case shown (R equals 25 deg/sec) between five and ten correction intervals will be required before the system "settles down", the exact number of oscillations depending on the size of the initial disturbance.

Reducing the runaway velocity by a factor of four avoids self-sustained oscillations. They also can be avoided by increasing the inactive zone width by a factor of four. The latter is accomplished on the plot by dividing the describing function of the contactor by this factor (hence multiplying the scale of the $-G_D^{-1}$ locus by four.) This avoids loci intersections (no oscillations), but the improved stability is at the expense of static accuracy.

Stability can be effectively improved without sacrificing either static accuracy or speed of response by the introduction of compensating networks similar to those used to improve linear systems. A modification of the G locus, easily computed and plotted, takes into account the effect of such networks in the describing-function method.

The phase-plane method would not ordinarily apply once these networks were introduced because the system would no longer be describable by a second-order differential equation. This points out one of the major advantages of the describing function method for the achievement of nonlinear system synthesis.

Thus, the describing function is:

- more adaptable to the problems of synthesis and
- not materially complicated by complex dynamics in the linear part of the system.

Analyzing Other Nonlinear Effects

Some nonlinear problems involve backlash of gears and couplings coupled to inertia loads or velocity or acceleration limiting. In these cases a clean division between the frequency-dependent and amplitude-dependent components (as occurred in the previous example) may be difficult and preclude the superimposing procedure. But analysis is still possible by drawing families of describing-function loci, one for each operating amplitude. This complicates the graphical procedure, but is still generally feasible.

Besides being applied to the analysis and synthesis of contactor systems, the describing-function method has been employed to analyze the effects of backlash[13], various types of limiting[14], coulomb friction[15], and many other nonlinear effects in feedback control systems. It should be kept in mind that this is an approximate method and that it provides sufficiently accurate results in most, but not all, instances. There are a few situations where the system has insufficient low-pass filtering action to justify the assumption of neglecting the higher harmonics. A check on the validity of this approximation should always be made.

Recent work[16] extends the describing function concept to the analysis of nonlinear systems subjected to random disturbances that can be described by statistical means. This greatly increases the utility of the method and makes it applicable to problems in which the response to various types of noise disturbances is of interest.

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Temporary Storage Elements and Special-purpose Tubes

Professor Scott rounds out his discussion of circuit devices with a description of various "short-time" storage elements, which, like the gating circuits covered last month, are basic to the digital computer. He also details the theory and advantages of certain special-purpose tubes that are used in computers for coding, counting, and switching.

NORMAN R. SCOTT
University of Michigan

Many computers have dynamic circuitry, in which the presence or absence of pulses at regularly spaced "clock" pulse times indicates the binary digits 1 and 0. Other computers have static circuitry, in which information is represented by either one of two dc voltage levels. Both of these systems need at least one of the gating techniques described last month and at least one of the small-capacity memory elements to be discussed now.

DELAY LINES

Timing is an extremely important problem in dynamic circuitry, since all operations must be synchronized by the pulses on a clock bus. One megacycle is a typical clock pulse frequency. The small delays due to finite rates of pulse rise or due to transmission times from one part of the computer to another cause pulses which should be in time coincidence to be out of step. Compensating delays must be introduced to restore coincidence. In addition, logical considerations often require that information occurring at one clock pulse time be held over until the next clock pulse. The required delays, usually between a fraction of a microsecond and several microseconds, can be caused conveniently by electrical transmission lines.

Many factors must be considered when selecting or designing a delay line; chiefly: the delay time, the

FIG. 1. One section of a lumped-constant delay line.

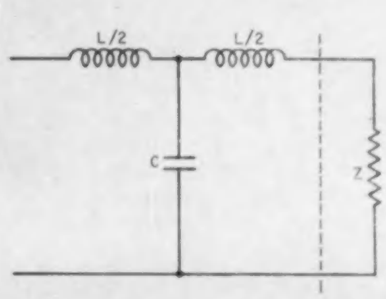


FIG. 2. Characteristic impedance of a lumped-constant line vs. frequency.

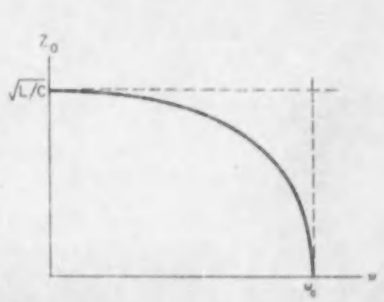
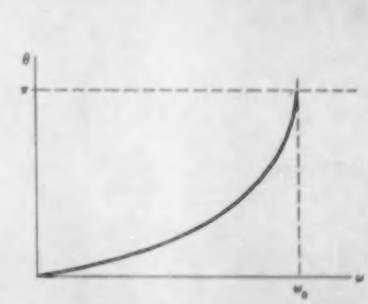


FIG. 3. Phase shift vs. frequency in a lumped constant line terminated in Z_0.



characteristic impedance, the output pulse rise time, and the pulse distortion[1]. These are not independent, so the problem can become very involved.

In any transmission system, distortion can be avoided by making the amplitude response constant over the frequency spectrum of the signal and making the phase-shift-vs.-frequency characteristic a constant slope. If the gain (or attenuation) factor of the system varies with the frequency, amplitude distortion results. Change of the phase-shift curve from constant slope produces phase distortion or, as it is sometimes called, delay distortion. A square pulse transmitted through a system with only amplitude distortion will be distorted symmetrically about its midpoint in time, since its (Fourier) component sine waves are all in phase and undergo changes of amplitude relative to one another but no changes in phase. Phase distortion, however, produces an asymmetry, because the high and low frequency components are delayed unequally. The output may be oscillatory followed by a rounded pulse, or a rounded pulse with an oscillatory ending, depending on whether the high frequency components arrive first or last.

Electrical delay lines may be either the distributed-parameter type or the lumped-constant type. The lumped-constant delay line is a fairly simple conventional low-pass filter like that shown in Figure 1. The characteristic impedance of a line comprised of such sections is:

$$Z_o = \sqrt{L/C\,(1 - \omega^2 LC/4)}$$

Cutoff occurs at the frequency at which Z_o ceases to be resistive and becomes reactive, i.e., at

$$\omega_o = \frac{2}{\sqrt{LC}}.$$

Thus we may write:

$$Z_o = \sqrt{\frac{L}{C}} \cdot \sqrt{1 - \left(\frac{\omega}{\omega_o}\right)^2}$$

Figure 2 shows a plot of Z_o vs. ω, which shows that a resistance $R = \sqrt{\frac{L}{C}}$ is a matched termination only at frequencies $\omega << \omega_o$.

For a lumped-constant line terminated in Z_o, the phase shift per section is

$$\theta = 2 \sin^{-1}\left(\frac{\omega}{\omega_o}\right)$$

A plot of this is shown in Figure 3. Only for $\omega << \omega_o$ does this delay line show a constant amplitude response from one stable state to the other; and a phase shift proportional to frequency.

Complete design of a delay line is an advanced problem in filter theory[2], but some approximations will indicate typical magnitudes. Suppose it is desired to transmit a pulse with a rise time of 1 microsec. A fairly good rule of thumb shows that $1/T_r = 10^6$ cycles should be adequate bandwidth. Because the delay time T_d for any frequency component is $\frac{d\theta}{d\omega}$,

$$T_d = \frac{2}{\omega_o \sqrt{1 - \left(\frac{\omega}{\omega_o}\right)^2}} \text{ sec}$$

Evidently the delay increases rapidly as $\omega \rightarrow \omega_o$; components in this range, therefore, arrive too late to assist in the initial rise of the output voltage. Because frequency components up to

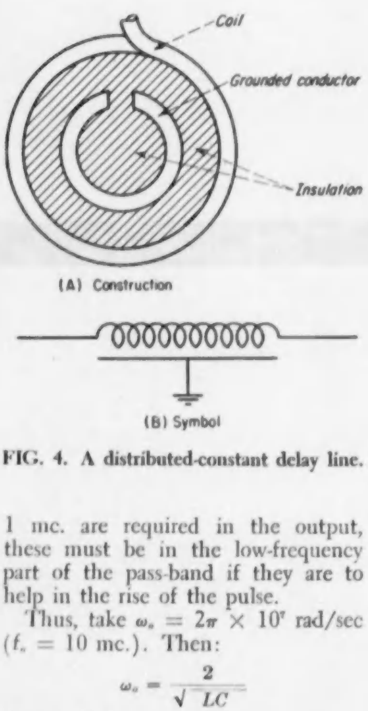


FIG. 4. A distributed-constant delay line.

1 mc. are required in the output, these must be in the low-frequency part of the pass-band if they are to help in the rise of the pulse.

Thus, take $\omega_o = 2\pi \times 10^7$ rad/sec ($f_c = 10$ mc.). Then:

$$\omega_o = \frac{2}{\sqrt{LC}}$$

From which:

$$LC \leqq 10^{-15} \text{ sec}^2$$

For Z_o of 500 ohms, we find then that $L = 16$ microhenries and $C = 63$ mmfd. For low frequencies the delay is given approximately by $2/\omega_o \cong 0.03$ microsec. Thus a 3-microsec delay would require about 100 such sections.

Much better results are obtained from low-pass filters having mutual inductance, and considerable work has been done on delay lines like these[3].

Lumped constant delay lines are useful where the characteristic impedance must be made low, where the voltage is high, or where simplicity of construction is important. They usually have lower attenuation than distributed lines because a lower-loss dielectric can be used in the capacitors.

One form of distributed-constant line is made by winding a coil with the desired inductance over an insulating form in which is imbedded a grounded conductor which does not form a closed turn, as in Figure 4. The shunt capacitance of such a line is considerably higher than without the center conductor, and consequently the delay per unit length is longer. Such lines often have considerable delay distortion, however, since the effective inductance decreases with increasing frequency. This is because flux linkages along the line are not in phase when the wave length becomes comparable to the line length. The phase characteristic can be equalized by making the effective capacitance increase with frequency to offset the drop in L. Such an effect is obtained by including an isolated conducting strip in the line in addition to the grounded conductor. Because the strip is isolated, the net current flow to it is zero. Therefore, at low frequencies, where there is negligible phase difference along the portion of line opposite a given strip, there will be no current flow from any turn of the coil to the strip although there is capacitive current flow to the grounded conductor. At high frequencies, however, the additional strip acts like a grounded conductor, and its capacitance adds to that of the grounded conductor.

FLIP-FLOPS

The flip-flop circuit used in static machines is based on the Eccles-Jordan multivibrator circuit. This circuit is useful in completely static machines and in machines using both static and dynamic circuitry.

Vacuum Tube Flip-flops

The basic circuit for the static flip-flop is shown in Figure 5. The behavior of the circuit depends on the impedances Z_1 and Z_2, which together determine whether it will be bistable, monostable, or astable.

The bistable circuit is stable with either A conducting and B off, or B conducting and A off. A single input pulse is required to change the circuit from one stable state to the other;

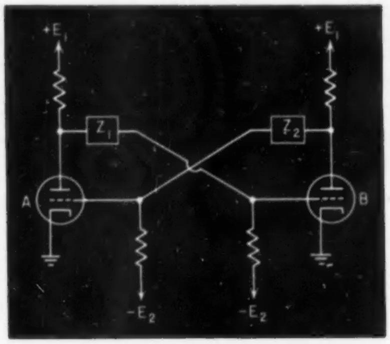


FIG. 5. Basic vacuum tube flip-flop.

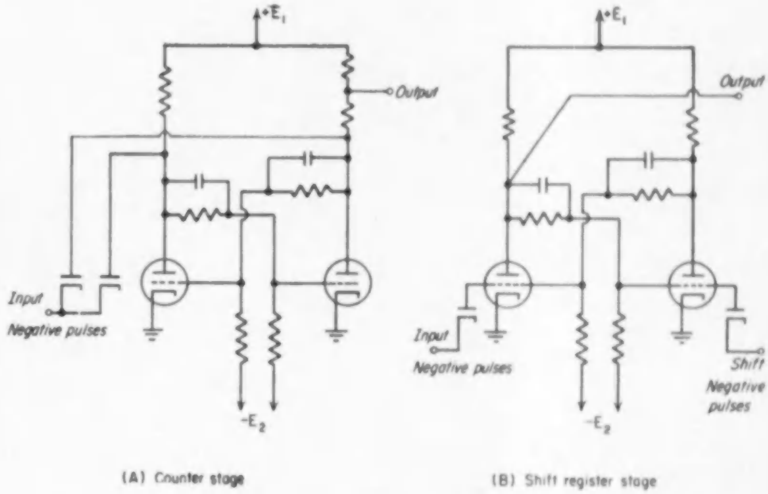


FIG. 6. Bistable flip-flops.

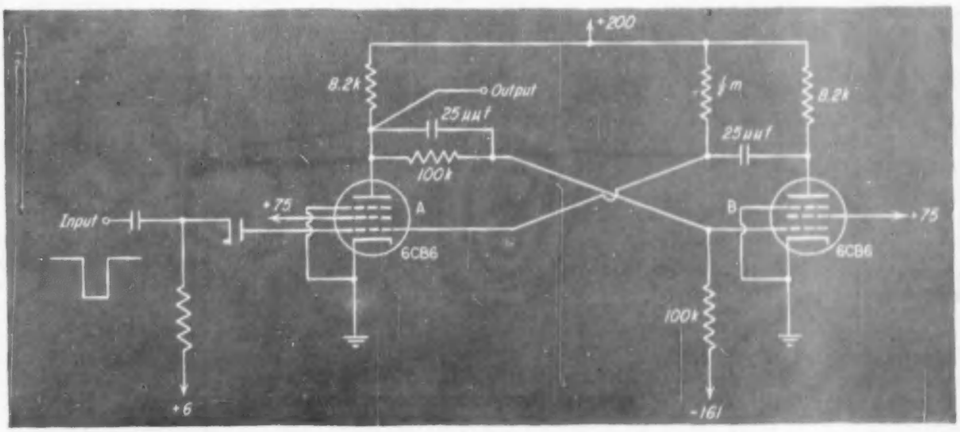


FIG. 7. Delay flip-flop used at the University of Michigan.

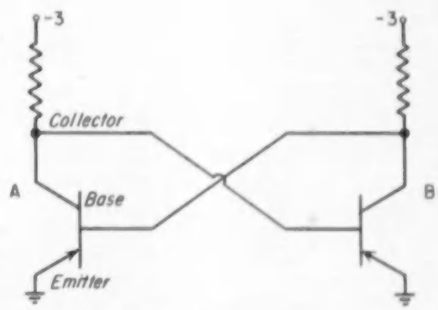


FIG. 9. Basic transistor flip-flop.

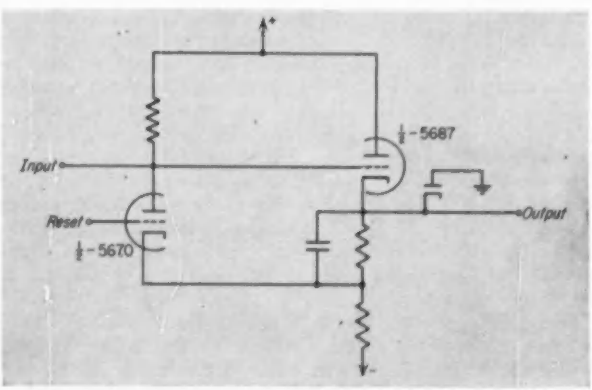


FIG. 8. Asymmetrical flip-flop used in the NAREC.

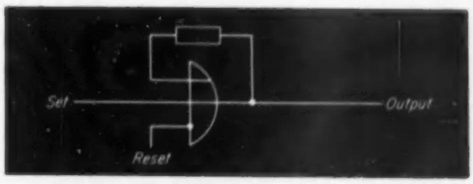


FIG. 10. Logical circuit for a dynamic flip-flop. In practice, pulse reshaping circuits must be added.

thus, two pulses will carry it through a complete cycle. The circuit will be bistable only if both Z_1 and Z_2 contain dc paths. Typically, Z_1 and Z_2 are identical parallel RC branches.

The monostable circuit has only one stable state and always returns to this state after having been triggered temporarily to the other one. One of Z_1 and Z_2 should have a dc path and the other should not, to make a monostable circuit. For instance, if Z_1 is a parallel RC circuit and Z_2 is pure capacitance, the quiescent grid voltage of tube A is minus E_2 volts. A is cut off and B conducts. If A is triggered into conduction, it will remain on only until the charging current through Z_2 becomes too small to hold grid A above the cutoff potential. Each input pulse causes the monostable circuit to execute a complete cycle.

The astable circuit has no dc path in either Z_1 or Z_2 and oscillates from one unstable condition to the other at a rate determined largely by the time constants of the charging paths of the capacitors. No input pulses are needed to shift this circuit from one state to the other.

The bistable flip-flop is a one-bit storage device. It may be used merely to retain information until it is needed, or it may be used as a trigger circuit, exerting on-off control over other circuits according to the information it is storing. The use of the circuit determines its design, because input and output conditions vary in different applications. For example, as a counter, the circuit requires symmetrical inputs, but as a stage in a shift register it requires separate inputs for information pulses and shift pulses, as shown in Figure 6. The output voltage divider is sometimes necessary to attenuate the pulse fed through from the input directly to the output.

For trigger circuit applications the circuit is very similar to Figure 6B except that the inputs might be labeled "set" and "reset" instead of "input" and "shift". The bistable flip-flop makes a trigger of adjustable on or off duration, because its control action can be terminated at any time by resetting the flip-flop.

The monostable flip-flop, sometimes called a "one-shot multivibrator", can be used as a delay circuit for the short-time storage of one bit or can be used as a trigger circuit of fixed duration. A typical circuit is shown in Figure 7. This circuit is different from that of Figure 5, in that grid A has a pull-up resistor to plus E_1 instead of a pull-down to minus E_2. Thus tube A is normally on. A negative-going pulse of sufficient magnitude turns A off and B on. As the capacitor at the plate of B charges through the ½-megohm resistor, grid A rises toward cutoff and tube A then conducts again, cutting off B. While B conducts, input pulses have no effect on the circuit. During this interval, either the low potential of anode B or the high potential of anode A can be used to control another circuit.

The astable flip-flop is of little use to the computer engineer, because its state is so largely a function of its own parameters and so little a function of external information signals. The circuit is a useful frequency divider, since it can be synchronized at a sub-multiple of the frequency of an external wave; but this function is of more use in television and radar work than in computer design.

Three problems exist in selecting circuit constants for the flip-flop:

▶ the dc problem—choosing resistors, voltages, and tolerances to minimize the effect of changing tube and component characteristics and maintain the initial stability of the circuit.

▶ the switching problem—choosing the circuit, the component sizes, and the layout so as to minimize the duration of the transients as the circuit switches from one state to the other.

▶ the loading problem—choosing circuit constants such that loading will have a minimum effect on dc stability or on switching speed.

The first two problems have been discussed extensively in the literature[4]. The third problem has been frequently encountered, but has been solved, more often than not, by "brute force" methods. One of these is to design the flip-flop as a high-power device with low impedances. Thus, it can be made comparatively insensitive to large load variations. Another method is to couple the flip-flop to a cathode follower, which in turn can drive subsequent circuits. But introduction of additional cathodes complicates the maintenance problem and should be done only when the additional components actually result in wider operating margins and tolerances for the circuit. Still another solution is the asymmetrical flip-flop, in which the tube from which the output is taken is connected as a cathode follower. Such a circuit is used in the NAREC, as shown in Figure 8.

Transistor Flip-flops

Static flip-flops can be made from transistors also, and in this form they may be either direct adaptations of the Eccles-Jordan vacuum tube circuit, or back-to-back connections of the grounded emitter switch using alloy junction or surface-barrier transistors[5]. This latter circuit is a particularly simple one, as may be seen from Figure 9. If the transistor A is in the on state (saturation), heavy base and collector currents flow. Since the collector is then only a few millivolts below ground, transistor B has only small base and collector currents and may be regarded as in the off state. The other stable state for this circuit is with B on and A off. The circuit may be made to change state by driving the base of the on transistor up toward ground.

Dynamic Flip-flops

Computers with dynamic circuitry use a kind of flip-flop which is very different from the static flip-flop. This "dynamic flip-flop" produces a continuous stream of pulses when it is in the on (or "set") condition and produces no output pulses when it is off (or "reset"). Such a device can be made by feeding the output pulse of an OR gate back to its input through a section of delay line. If the delay is made equal to the clock pulse period, then the output pulses are at clock frequency. The device is reset by inhibiting one of the fed-back pulses. Figure 10 shows the basic circuit, but some pulse amplification and reshaping must be included in the loop to avoid deterioration of the pulse. In SEAC circuitry[6], discussed last month, such amplification is included with each stage of gating. Hence the dynamic flip-flop is made up very easily.

SPECIAL-PURPOSE TUBES

Special-purpose tubes may make it possible for the computer engineer to simplify complicated circuits involving a large number of general-purpose tubes, or to modify the logic of his machine in ways not practical with general-purpose tubes. For example, a single special tube for decimal-to-binary conversion could replace a complicated matrix circuit. Again, tubes with ten stable outputs make decimal arithmetic a much more practical matter.

Special-purpose computer tubes may be classified in the following categories, according to their use:

▶ switching or counting tubes

▶ coding tubes

▶ arithmetic tubes

▶ storage tubes (to be described in a later article in this series).

SWITCHING AND COUNTING TUBES

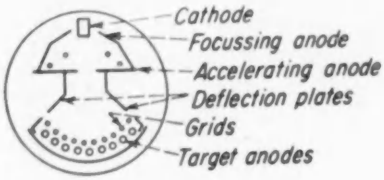


FIG. 11. Electrostatically focused beam switching tube.

Switching and counting operations are quite similar, although some tubes are designed to perform one function and some the other. In fact, many tubes of this type can perform both these functions. Such tubes usually have a common cathode and a number of anodes, and either electrostatic or electromagnetic focusing, which allows the current to flow to only one of the anodes at a time. If the anodes are brought to external connections, and if a fixed relationship exists between the control signals and the particular anode that conducts, then the tube may be used as a switching device. For counting, it is not necessary that each anode be brought to an external connection but only that successive identical control signals shift conduction to successive anodes and that some output signal be produced when the cycle of rotation of conduction starts again.

Electrostatically-focused tubes of this type are usually about the size of receiving tubes and use a ribbon-shaped electron beam rather than a pencil beam. Beam-forming is simpler than in cathode-ray tubes, and as a result a large fraction of the cathode current stays in the beam instead of being diverted to beam-forming electrodes. Since current density can be much lower for a given total current with a ribbon beam than with a pencil beam, space charge effects are negligible. High current can be obtained with low accelerating potentials, 1 milliamp at 250 to 300 volts being typical. Figure 11 shows a cross-sectional view of such a tube.

Electronic switching tubes can also be made with conventional cathode-ray tube geometry. One such tube, described in the literature[7], has been called a cyclophon. In this tube the usual electron gun structure, together with either electrostatic or magnetic deflection systems, produces a pencil beam which can be directed through any one of 25 holes arranged around the edge of a circular aperture plate. Twenty-five individual anodes, each brought out to external connections, are placed behind the 25 holes. In this form the device has moderately high output impedance and puts out a current of about one milliampere through a resistance of 50,000 ohms. Coating the anodes with secondary emitting material permits output currents of 30 milliamperes through 1,000 ohms.

A useful electromagnetic focusing method is one that relies on change of magnitude of the electric field to change the beam position. Tubes using crossed electric and magnetic fields to produce trochoidal electron motions have been called trochotrons in Sweden, where they were first developed. They depend upon the fact that electrons released into crossed electric and magnetic fields move in a trochoidal path along an equipotential line of the electric field. The rudimentary tube in Figure 12 shows this idea[8].

Electrons from the cathode are attracted toward element 11 but the magnetic field results in a trochoidal electron path along an equipotential line following the grounded guide element 1, and the current flows to 2. If any guide element, e.g. 5, is dropped in potential, the equipotential line followed by the beam enters the preceding box and current goes to 6 (and partly to 5). This is a stable position for the beam, because any increase or decrease of current to 5 will change its potential and hence the equipotential lines in such a way as to bring the beam back to its initial position. Successive pulses on line A move the beam along from 2 to 4, 6, 8, 10, and finally 11. The drop in potential at 11 and the trochoidal motion of the electrons combine to cut off the beam current momentarily, upon which initial conditions are restored and current flow to 2 resumes. A version of this tube is currently being manufactured commercially in this country.

In all the magnetically focused tubes the duration of the switching pulse must be carefully controlled. Too short a pulse prevents switching and too long a pulse may cause the beam to move more than one position. The direction of beam rotation (in circular versions) depends upon the direction of the magnetic field. This calls for a reversible counter, which may be made by paralleling two tubes with oppositely directed magnetic fields, keeping one cut off while the other counts and then transferring the count of the active tube to the one cut off and cutting off the formerly active tube.

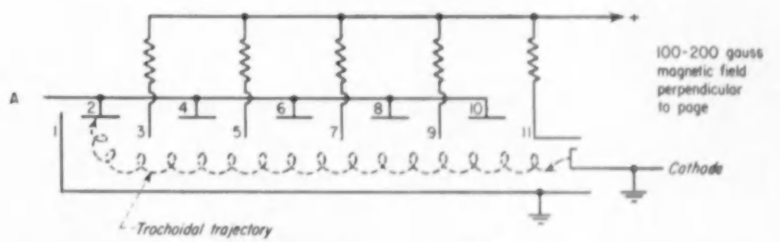


FIG. 12. Rudimentary trochotron, which uses crossed electric and magnetic fields.

CODING TUBES

Tubes for coding input signals into some form of binary output use most of the geometries and focusing arrangements described for switching tubes. The only other important differences in coding tubes are the codes used and the method of output, i.e., serial output or parallel output.

One simple form of coding tube uses a conventional electron gun, horizontal and vertical deflection plates, and a coding plate backed by an anode for each binary digit in the output, as in Figure 13.

A coding plate is shown in Figure 14. The beam is first deflected vertically by an amount corresponding to the signal to be encoded and then deflected across the coding plate to produce signals serially at the various anodes that it strikes. Simultaneous outputs of all binary digits could be obtained with a gun structure producing a ribbon beam that would simultaneously illuminate all digit columns.

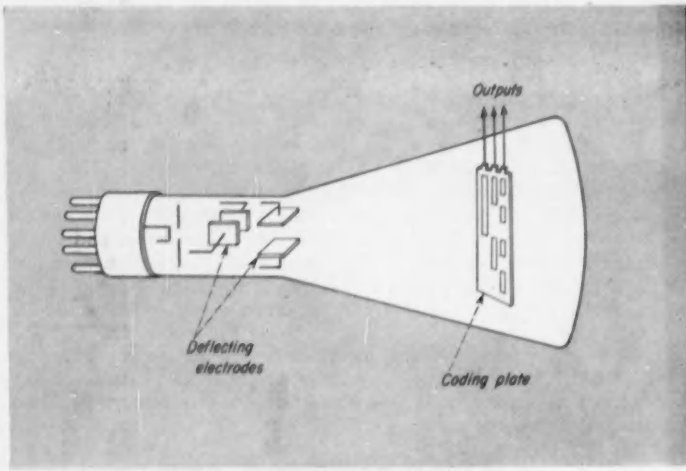


FIG. 13. A special plate makes a coding device out of an ordinary cathode-ray tube.

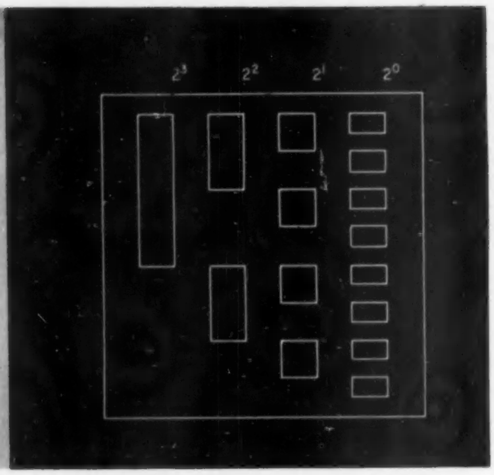


FIG. 14. A typical coding plate.

ARITHMETIC TUBES

An adder tube with very interesting possibilities has been devised by Kates. It has three anode segments, each with a hole in its center backed up by a target element, and in addition, target elements behind the spaces between anode segments, as in Figure 15.

Positive voltages are applied to anodes A, B, and C according to whether the addend, augend, and carry-in digits respectively are 0 or 1. If only one digit is present, its anode draws current, some of which passes through the hole to a T_1 target. If any two digits are present, the current flow is to two anodes and through the space between them to a T_2 target. If all three digits are present, current flow is symmetrical to both T_1 and T_2 elements. The three T_1 targets should be connected together to produce the sum digit and the three T_2's to produce the carry-out digit.

The wide variety of devices considered in these articles is evidence of the rapid changes that are taking place in computer technology. There is no evidence that the pace is slowing down, and the next few years should see the development of many more computer circuits.

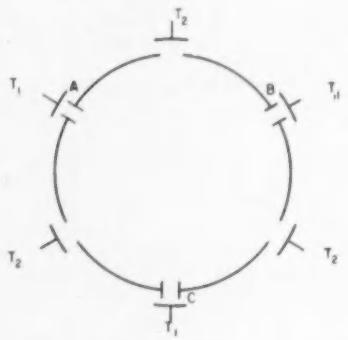


FIG. 15. The Kates adder tube.

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A biography of Professor Scott accompanied his article on computer gating circuits in last month's issue of Control Engineering.—*Ed.*

Small-scale Computers as Scientific Calculators

For those who can't afford to rent or buy a large-scale computer, or who do not need its huge capacity, there are many small-scale computers on the market. These smaller units play, in fact, a more important role in the professional life of the average engineer, since they are the ones he's more likely to be concerned with. Authors Carr and Perlis span the general-purpose calculator field by surveying and comparing these lower-priced machines.

JOHN W. CARR III, University of Michigan, and ALAN J. PERLIS, Purdue University

In contrast to the "million dollar machines" discussed in A *Comparison of Large-Scale Calculators*, CONTROL ENGINEERING, February 1955, is a larger class of "medium" to "small" computers in the "under $200,000" range. Even this distinction is not exact, since many of the latter group are modular devices that can be rented or bought in increasingly larger ensembles and may cost, with their peripheral equipment, as much as half a million dollars. Nevertheless, most of the scientific installations do not need as many tape units, as much input-output buffering, or as much peripheral equipment as do data-processing groups.

More than ten different commercial makes of computers, all within this general definition of "small", will be discussed. Only the *stored program* digital computers are listed. This eliminates such well-known computers as the IBM CPC and the UNIVAC 60 and 120, the whole class of digital differential analyzers, and other special-purpose computers. Too, such devices as the UNIVAC File Computer, designed solely for data-processing applications, are not included, although these machines, with some ingenuity, could be used to perform scientific calculations. All use a magnetic drum as the primary storage device.

Within the overall definition of "small", one can differentiate between "high-priced", "lower-priced", and "desk-type". The IBM Type 650 Electronic Data Processing Machine, ElectroData Corp.'s Datatron, the National Cash Register 102d, the Miniac of the Marchant Research Corp., and the Elecom 120 of the Underwood Corp. fall into the first category. The Elecom 125, designed primarily for business data processing, and the File Computer also belong in this category, in which prices range from $80,000 up, depending on "extras".

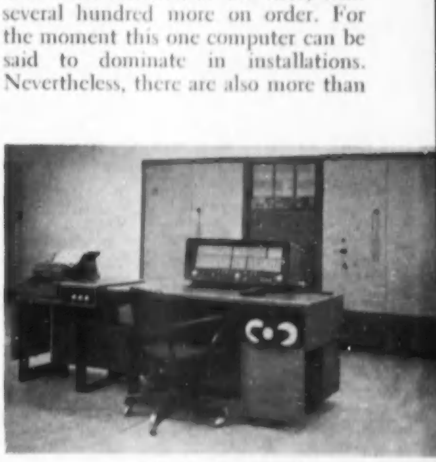
The "lower-priced" stored program machines include the Alwac, of Logistics Research, Inc., the Circle, of Hogan Laboratories, and the Bendix G15A, of Bendix Computer Div. In addition, the Readix, of the J. B. Rea Co., and the LGP-30 computer recently announced by Librascope, Inc., should be included in this category, as well as several British computers.

Finally the E-101 of the Burroughs Corp., the Monrobot of the Monroe Calculating Machine Co., and the Elecom 50 of the Underwood Corp., can all fit easily into a "desk-type" structure. They are generally controlled with an accounting machine or similar keyboard for hand input.

Whether further copies of the Circle computer and the NCR-102d will be built is problematical. Nevertheless, enough copies of these two computers exist to warrant their inclusion. The NCR-303, a more advanced version, was announced at one time as a successor to the 102d, but has since been canceled to allow for a newer design.

Most of the so-called "small" computers are decimal machines, the exceptions being the Alwac, Circle, LGP-30, and G15A, which are binary. They have been planned for use as both scientific calculators and data processors, so that the almost universal decimal system is no accident.

Over 150 copies of the Type 650 have been installed in the field, with several hundred more on order. For the moment this one computer can be said to dominate in installations. Nevertheless, there are also more than



The ElectroData Datatron

The Librascope LGP-30

TABLE I CHARACTERISTICS OF

COMPUTER	PURCHASE PRICE, $	MONTHLY RENTAL, $ (NOTE 5)	NUMBER OF TUBES AND DIODES	POWER AND EXTERNAL COOLING REQUIREMENTS	WORDS OF INTERNAL STORAGE (NOTE 7)	AVERAGE ACCESS TIME, MILLISEC	NUMBER OF ADDRESSES IN INSTRUCTION	NUMBER OF DIGITS PER WORD
Type 650		3,250 3,750 (Note 1)	2,200 tubes 4,000 diodes	16KW. No external cooling required, but air conditioning recommended	1,000 or 2,000	2.4	1+1	10
102d	99,500	2,400 4,100 (Note 2)	300 tubes 4,000 diodes	6KW. No external cooling required	1,024 +8	12.5 1.5	3	10
Datatron	136,000	4,333	1,200 tubes 3,000 diodes	13KW. Air conditioning recommended	4,000 +80	8.5 0.85	1	10
Miniac	100,000		700 tubes 1,500 diodes	4KW. No external cooling required	4,096 +256	5 1.25	1	10
Elecom 125	97,000	3,500 (Note 6)	350 tubes 4,000 diodes	7KW. Room air conditioning recommended	1 to 10,000 +10 to 100	8.5 1.8	2	10
Alwac	60,000		280 tubes 5,000 diodes	5KW. No external cooling required	4,096 +128	25 4.2	1+1	32
Circle	57,000 78,000 (Note 3)		700 tubes in 18 different chassis	3½KW. No external cooling required	1,024	8.5	1	40
Bendix G15A	45,000		400 tubes 2,800 diodes	3KW. No external cooling required	2,176 +4	29 0.6	2+1	29
Readix	79,000		260 tubes 3,040 diodes	5KW. No external cooling required	4,000 +160	9.0	1	10
Librascope LGP-30					4,096 (words "interlaced")	9	1	32
Monrobot	75,000		650 tubes 200 diodes	No external cooling required	100 nos. 100 orders (Note 12)	16	4	20
E-101	32,500 (Note 4)	850	160 tubes 1,500 diodes	3KW. No external cooling required	128 orders (pinboard) 100 nos.	9	1	12
Elecom 50	17,000		160 tubes 2,000 diodes	2KW. No external cooling required	2,400 orders (metalized tape) 100 nos.	35	1	10

1. Type 650 rental is for 1,000 and 2,000 word storage respectively.
2. 102d rentals are for five and one year lease respectively, with latter including magnetic tape unit.
3. Circle prices are for a 1,024 and 4,096 word memory respectively.
4. Purchase price of E-101 includes 1 year of free maintenance by Burroughs engineers.
5. All rentals include free maintenance, with the kind of maintenance depending on local conditions.
6. Rental for Elecom 125 includes a magnetic tape drive.
7. Words of internal storage also lists "rapid-access loop", if any.
8. Standard speed is stated in terms of the evaluation of A+B=C, C+D+E=F, and G×H=I, to compensate for the different number of addresses in various instruction codes.
9. Where given, the speeds using optimum programming are for optimum spacing of instructions only which, properly speaking, is only available on those machines having 1+1 or 2+1 instruction codes. In general, it is more difficult to optimum code for operand location.
10. The relatively high speed of the Datatron is attained by having both operands and instructions in the high-speed 80-word memory. In normal operation, practically all instructions and nearly all operands are so situated. This is actually a normal mode of operation.

THE SMALL COMPUTERS

NUMBER SYSTEM	STANDARD OPERATIONS PER SEC (NOTE 8)		INPUT IN DIGITS PER SEC (NOTE 14)			OUTPUT IN DIGITS PER SEC (NOTE 14)	
	NORMAL MODE	OPTIMUM PROGRAMMING (NOTE 9)	FLEXOWRITER	CARD READER	PHOTOELECTRIC READER	FLEXOWRITER	CARD PUNCH AND PRINTER
Decimal	22	33		200 punched cards per min; 265 digits per sec			100 punched cards per min; 132 digits per sec
Decimal	16		10 digits per sec		200 digits per sec	10 digits per sec	132 digits per sec from IBM 532
Decimal	50- (Note 10)		10 digits per sec	*150 digits per sec from IBM 513, 514, 517, 523; 300 digits per sec from 528	540 digits per sec	10 digits per sec (typewriter), 14 digits per sec (tape punch)	150 digits per sec from IBM 513, 514, 517, 523, 528
Decimal binary	12-20		10 digits per sec		1,000 digits per sec	10 digits per sec	Line printer available at extra cost.
Decimal	13-20 (fixed or floating point)		10 digits per sec; 60 char. per sec punch	*20 digits per sec from IBM 024; 150 digits per sec from IBM 523	200-400 digits per sec	10 digits per sec	20 digits per sec from IBM 024; 150 digits per sec from IBM 513; 100-200 digits per sec printer
Binary	8	15 (Note 11)	10 digits per sec	150 digits per sec from IBM 523		10 digits per sec	150 digits per sec from IBM 523
Binary	7.5		10 digits per sec			10 digits per sec	
Binary	10	? (Note 13)	15 digits per sec (tape reader)		200 digits per sec	10 digits per sec (typewriter); 15 digits per sec (tape punch)	
Decimal	8.0		10 digits per sec	*100 cards per min	"varied"	10 digits per sec	*100 cards per min
Binary	11-20		10 digits per sec			10 digits per sec	
Decimal	1		10 digits per sec			10 digits per sec	
Decimal	2						
Decimal	15						

Both the E-101 and Elecom 50 use accounting machines for all data input and output. Instruction input is by pinboard and metalized tape, respectively. (See Notes 12, 15 and 16)

11. The Alwac word is divided into four syllables and the fast mode is to space the orders in a syllable in each alternate word. This gives the 15 standard operations per sec mentioned. Orders are carried out from the 64-word working storage.
12. The instructions in the E-101, Monrobot, and Elecom 50 are physically distinguishable from the number storage and represent a departure from the accepted trend in computer design.
13. The G15A programming procedure is so unlike standard ordinary or minimal access programming that a normal comparison cannot be made unless many variables not occurring in other machines are fixed. A factor of two or three is apparently possible with complex coding effort.
14. The * refers to auxiliary, usually IBM punched-card, equipment. The adaptor units for the various IBM machines introduce additional costs that may run from $10,000 to $20,000. Of course, the rental of the IBM machines is also additional. The 024 and 523 rent for $30 and $65 per month respectively.
15. The input to the E-101 is by manually operated keyboard for data, and by a manually (pre)set pinboard for instructions. Further data can be read in by a ten-character per sec paper-tape reader.
16. The input to the Elecom 50 is by a manually operated keyboard for the introduction of data, and by a metalized plastic tape for instructions.

The Marchant Research Miniac

20 of the CRC-102 decimal and binary computers (as the NRC-102d was originally named), over 15 of the Datatrons, almost 10 Elecoms, and several each of the Miniacs, Alwacs, Circle computers, and Monrobots. The Burroughs E-101 has been set up for assembly line production.

It is hard to tell whether the bulk of the present small machines is used for data processing, scientific calculations, or for both; but a sample list of Type 650 and Datatron users indicates that in the early stages at least half the installations are for scientific calculation.

The accompanying tables compare the characteristics of the "small" computers. These data were first collected by one of the authors in a personal survey of most of the organizations that were making equipment in 1954[1]. The information since has been extended by both authors to include later information and additional equipment.

The Bendix G15A

Programming Flexibility

Some of the most striking differences between the "small" computers become obvious only when they are programmed. For example, the "red-tape" bookkeeping and programmed arithmetic instructions that speed up the interpretation process for floating-point vary widely. In general, the overall efficiency of these computers, like that of their larger counterparts, depends upon their ability to properly use subroutines. At present only one of the smaller computers has the ability to modify the location of previously written instruction addresses without extensive programming. The design of the Datatron "B-line" or index register, similar to that of the IBM Type 704, is the earliest known use of this technique in the United States. B-lines, or tallies, as they are also called, will also be added to the Type 650 and the Elecon 125 within the coming year.

Several other smaller computers, as well as the Datatron, now have similar counting or indexing facilities, but not with the subroutine orientation feature. The Elecom 120, Readix, and E-101 possess such an automatic facility with their tally commands and stepping switch, respectively. It is estimated that two to four instructions per iterative cycle can be saved by these features.

An equally important subroutine programming feature, found on most of the larger computers, is a "return jump". By means of a transfer command, a subroutine can be successively entered from several program locations, with the point to which it should return control stored automatically. The command or control counter, during transfer, is always the machine register that contains the desired information. Only four of the computers (Datatron, Elecom 120, LGP-30, and Circle) have an instruction that transfers information from the command or control counter to the arithmetic unit or storage for future use.

All the small computers use fixed-point numbers; one copy of the Elecom 120, however, has floating-point. Optional floating-point will be added to the Datatron, Readix, and Type 650 sometime this year. Similarly, the analysis of variance and other statistical problems may call for double precision arithmetic. This large-computer facility is available in only one smaller machine—the type 650. Addition into the low-order positions of the accumulator is extremely valuable in this type of computation.

The Type 650 also has a "table look-up" instruction, which automatically searches a table in memory to extract a specific word. This process must be programmed in all the other computers.

Storage and Displays

Certainly the Datatron, Readix, and Elecom 125, with 4,000 words, and the Miniac, LGP-30, and Alwac, with 4,096 words, lead the smaller computers in available storage space. And storage is especially important when no magnetic tape unit is available. At the other extreme are the E-101, Elecom 50, and Monrobot, planned for problems requiring at most 50 or 100 numbers.

There is quite a bit of difference in the way the small computers present the internal state of the key registers to the user. For example, the Type 650 has no method for printing the contents of any of the internal locations (in the future, a direct printer is scheduled as an optional feature); the user must depend on a one-at-a-time biquinary decimal light display of the important register contents. The Elecom 120 does allow access to key registers, but only by typing out the contents. In the Datatron, all registers are displayed at all times, but the contents cannot be typed out. Most of these computers permit manual stepping from one program instruction to another, a feature that is more useful for machine debugging than for program checking.

Devices for Speeding Up Operation

Many computers on the list have some method for reducing the "wait time", the time until the next instruction or operand comes under the reading or writing head of the magnetic drum. These methods involve increased programming effort. Two general techniques are used: a "next instruction address" (Type 650, Alwac, and G51A), and a rapid-access loop (most of the others). A rapid-access loop uses two heads on one drum track, repeatedly reading and writing a number of copies of a smaller block of information on the track, so that the next passage of information beneath the magnetic head takes a much shorter time. The G15A and Alwac combine these two techniques with rapid-access lines and a "timing number" or "optimum address", which is the equivalent to the Type 650 "next instruction address".

The efficiency of writing programs for a rapid-access loop varies with the amount of storage in the loop. Only the Datatron, with 80 words, the Miniac with 256 words, the Alwac and LGP-30 with 128 words, and

the Readix, with 120 words, have enough storage to make programming with rapid-access loops relatively easy compared to the Type 650 "optimum coding" procedure. The latter stores operands and instructions at the proper time, so that the information will pass under the magnetic head without a lengthy wait. Moreover, of these, only the Datatron allows easy use of instructions in the rapid-access loop; the result is the relatively high speed noted in Table I.

One of the authors has programmed the Type 650 and Datatron computers on several large and relatively complicated problems, in an attempt to compare programming difficulty. Despite experience and use of the rules given for both computers, "human" coding of both machines is equally difficult. At first the Datatron system appears to have a higher machine speed; but use of the various "minimal access coders" or automatic program reshufflers devised by such organizations as Datamatic, Inc., of Waltham, Mass., and the Equitable Life Assurance Society of New York, permits the Type 650 to perform a rough minimal access rearrangement of its own instructions and data that may speed up the program over normal sequential coding by a factor of 1.5 to 2. As yet no automatic coding technique for speeding up Datatron programs has been written, although this is possible within limitations, as in the case of the Type 650 "minimal access coders".

Checking Facilities

To some extent the small-scale computers follow the design techniques of the larger computers in tackling error prevention and failure detection. In most cases, they have marginal checking features that vary several voltages to find marginal components. The Elecom 120 and 125 use an excess-three binary code for decimal representation. With this, the digit patterns 0000 and 1111, for example, never occur. All inputs and outputs from memory are checked for these excluded digit patterns. If they should occur, the machine stops and the cause of the error is somewhat isolated. The Type 650 and Datatron are similar in that they use the biquinary and straight binary code, respectively, for binary coding of decimal digits. Forbidden combinations occurring at check points in each computer result in an automatic machine stop. The computers, in general, also check memory selection by checking the address generator for a coincidence after a complete drum revolution.

Automatic Coding Procedures

The smaller computers generally do

TABLE II

AVAILABILITY OF MAGNETIC TAPES AS AUXILIARY STORAGE

COMPUTER (SEE NOTE 1)	WORDS PER TAPE	COST PER TAPE UNIT, $	READING OR WRITING SPEED, CHARACTERS PER SEC	AVERAGE TAPE SEARCH TIME, SEC	MAXIMUM NO. OF TAPE UNITS MACHINE CAN CONTROL
Type 650	220,000	750 each per month	(See Note 2)	?	6
102d	115,000	19,500	1,600	40	7
Datatron	160,000	14,700	5,000	98	10
Miniac	25,000	5,000	915	?	?
Elecom 120A Elecom 125	125,000	8,000	2,000-6,000	700	10
Readix	50,000	10,300	1,000	80	"several"

NOTES

1. Only those machines are listed for which the manufacturer provides tape units.
2. The IBM Type 727 to be connected with the Type 650 can read and write at a speed of 15,000 characters per sec, but the computer itself accepts information at a much slower rate.

TABLE III

PROGRAMMING CHARACTERISTICS

COMPUTER	A	B	C	D	E	F	G	H
TYPE 650	O	O	●	●	O	●	●	●
102D	O	O	●	O	O	●	O	O
DATATRON	●	●	●	O	●	●	O	●
MINIAC	●	●	O	O	O	O	O	O
ELECOM 120A	●	●	●	O	O	●	O	●
ELECOM 125					●			O
ALWAC	O	O	O	O	O	●	O	O
CIRCLE	O	●	O	O	O	O	O	O
READIX	●	O	O	O	O	O	O	●
LGP-30	O	●	O	O	O	O	O	O
G15A	O	O	●	●	O	O	O	O
ELECOM 50	O	O	O	O	O	O	O	O
MONROBOT	O	O	O	O	O	O	O	O
E-101	●	O	O	O	O	O	O	O

CODE

O No
● Yes

A. Automatic tally orders, conditional upon completion of a count.
B. Transfer control orders that automatically retain an address indicating the source of the transfer.
C. Automatic normalization of numbers for floating point and scale factoring.
D. Addition into high and low parts of the accumulator or of single and double length words.
E. Automatic modification of addresses by B register.
F. Transfer contol on +, O, −
G. Table look up.
H. Floating point (optional).

The Logistics Research Alwac

not reflect as much work in automatic programming devices, such as compilers and interpreters, as the larger computers. However, even if a manufacturer does not provide such a technique, chances are that one or more users have spent considerable effort in this direction. Thus, the more copies of a computer extant, the more likely efficient and varied automatic coding techniques will be available.

The Type 650 has semi-automatic coding procedures developed by IBM, but no full-fledged compiler, since its relatively small memory mitigates against elaborate subroutine compilation. As noted, several programs have been devised to aid minimal access programming for the Type 650. A large number of floating-point interpretive routines has been written, either by IBM or the various users, and there are therefore many choices available. Of course, all of these routines slow down a computer by a factor of perhaps four to ten.

Similar automatic coding procedures have been written for the Datatron. At present a subroutine compiler is now under test at Purdue University, and several floating-point interpretive routines are available among various Datatron users. A similar compiler has been written for the Elecom 125, while a conversion program from decimal to binary and binary to decimal comes with the Bendix G15A.

The interchange of information among users of the same machine is as important as actual working automatic routines. IBM holds seminars for Type 650 users and at the seminars new programs, coding techniques, and numerical methods are discussed. An interchange of information is underway among Datatron users, and other manufacturers indicate they are attempting to follow suit. The incipient purchaser of a computer should consider such available aids as positive features of a particular computer.

Input-Output

All these computers were originally designed for scientific and engineering calculations. The demands of data-processing applications have caused the computer designers to add more powerful input-output facilities (at a higher cost). Most of the machines (except for the Circle, E-101, Monrobot, G15A, and Elecom 50) have provisions for adding punched card readers and punches, and in some cases, tabulator-printers, to their present standard input-output, which is usually punched-paper tape via a photoelectric reader and an automatic typewriter. The standard input for the Alwac, Circle, LGP-30, Monrobot, and E-101 is a 10-digit-per-sec paper-tape reader, or comparably slow keyboard, which is intolerable in any computational laboratory requiring a large volume of results at a reasonable rate. A similar output rate is not intolerable, but a higher-speed paper-tape punch or punched-card input-output noticeably increases efficiency.

Magnetic Tape Equipment

Only the more expensive small machines now have magnetic tape units planned or available on a modular basis. The 102d, Readix, Datatron, Miniac, and Elecom 120 and 125 have them now, and the first units for the Type 650 will be produced this year. The characteristics of the magnetic tape units are listed in Table II.

These smaller machines, with several magnetic tape units added, may have rental or purchase prices almost a third to half that of the larger computers. Because of their magnetic tape equipment, they may compete satisfactorily in some data-processing problems with the larger machines. But in most scientific applications, the access time to storage, with the fundamentally low pulse-frequency, means that the basic computing speed has an upper limit still far below that of the larger computers. To improve this, some manufacturers have already made plans for adding magnetic core storage. IBM has announced future delivery of a small-size, high-speed core memory; ElectroData is designing a magnetic core prototype memory for the Datatron.

What may happen, of course, is that the smaller equipments will become more expensive as user acceptance grows, and the gap between them and the larger machines may be narrowed. Or perhaps the "small" machines of the future will have the speeds and facilities of the large ones of today.

Recommendations to a Future User

As long as the field of computers for scientific computation remains as fluid as it is today, it is worthwhile for every incipient computer user to delegate some member of his organization to follow the pattern of the field. The scientific calculator user who does not find out what is being done in other installations, and on other types of computers than his own, will fall behind in the competition for most efficient computer use. The development of applied logic and mathematics that is coming with the new machines foretells what may be the first rapid popularization of an exact science among a group of practitioners. The acquisition of knowledge in this new field does not end the day on which a computer is obtained. Much hard work and pooling of information lies ahead before any computer, small or large, reaches the peak of performance inherent in its fundamental structure.

In almost every installation, acquisition of a computer must be justified on a dollar basis. (Lucky is the research laboratory or procedures group where such intangibles as are offered by a digital computer are given a weighted dollar value.) The acquisition of a smaller computer, even though it may not be ideal and may have only a limited capacity for the problems to be handled, can lead to a larger equipment if used successfully. Provided it is not treated as a toy, it will enable engineers and business planners to investigate problems that may automatically justify a larger system.

Provide Valuable Training

The future user should not feel frustrated if his organization cannot at first acquire one of the larger computers. The smaller computers are in themselves as complete and general as the most expensive Type 704 or LARC. If used properly and with foresight, they may lead to larger devices; in any case, the training they provide is generally applicable directly to their more expensive counterparts. The organization that uses this new equipment efficiently and properly, no matter what its size or cost, will find its whole outlook on the solution of scientific and engineering problems changed markedly, its output increased, and its morale improved.

REFERENCE

1. *CHARACTERISTICS OF CURRENTLY AVAILABLE SMALL DIGITAL COMPUTERS*, A. J. Perlis, "Proceedings of the Eastern Joint Computer Conference", December 1954, American Institute of Electrical Engineers (1955).

How to Keep Blood From Freezing

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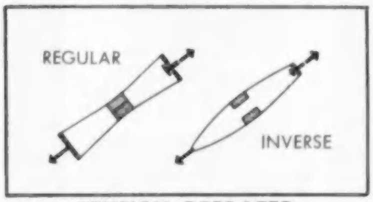
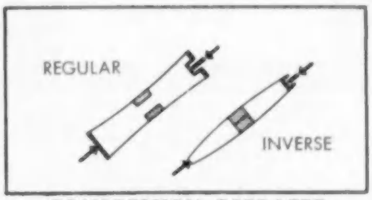
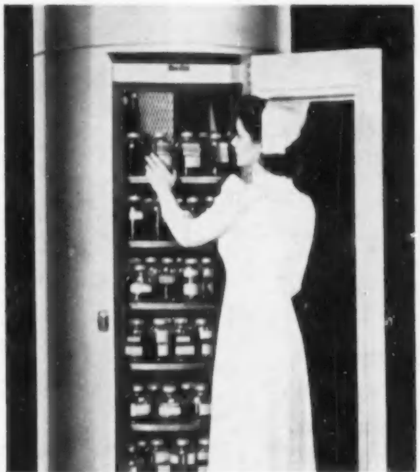
Fenwal Thermoswitch Controls are constructed as either tension or compression operated with regular or inverse contact arrangements.



TENSION OPERATED



COMPRESSION OPERATED



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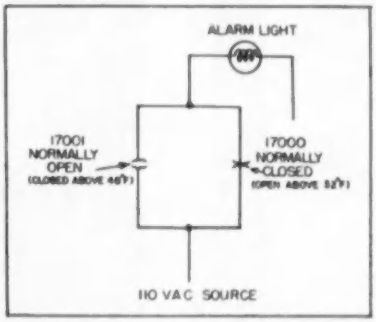
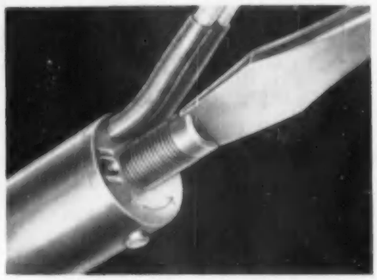


point without danger. Tension operated Fenwal Thermoswitch units may be set below 0°F but compression operated units are recommended if rapid temperature changes in excess of 100°F or extreme temperature overshoots are to be encountered.

The Fenwal Thermoswitch Control is constructed with two silver contacts mounted on, but electrically insulated from, curved nickel-iron struts of low expansion coefficient. This element assembly is then mounted under tension or compression in a seamless drawn brass or stainless steel tube. The amount of tension or compression is variable, depending on the position of the adjusting sleeve and the temperature of the shell.

Fenwal compression operated units may be exposed to a temperature of −100°F indefinitely, and to temperatures 400°F above their set temperatures for short periods of time.



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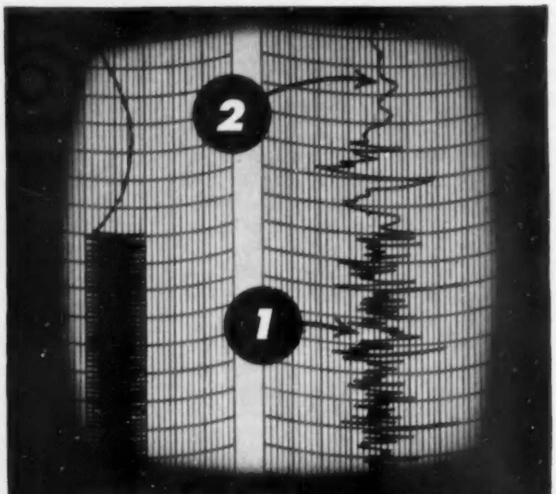


READABILITY

At (1) above typical signal is recorded at 10 mm. per second chart speed. At (2) unit is switched to 250 mm. per second speed to give optimum resolution. No interruption in recording.

All oscillographs have electrically controlled chart drive transmissions, permitting instantaneous switching and remote control. Choice of 8 or 16 chart speeds to give the best readability and economy for all signals.

FLEXIBILITY—Four and six channel oscillographs are physically interchangeable. A four channel unit, selected to meet present requirements, can be *expanded* to a six channel unit later. All oscillographs and amplifiers mount in standard 19-inch racks or consoles. Complete selection of amplifiers.

*Trade Mark

PORTABILITY—Complete systems designed for portable use simplify field testing and measurements. Units are light in weight, durable, easy to set up. Typical weights for oscillographs: 2-channel 25 lbs., 4-channel 38 lbs., 6-channel 51 lbs.

BRUSH ELECTRONICS COMPANY

INDUSTRIAL AND RESEARCH INSTRUMENTS
PIEZOELECTRIC MATERIALS • ACOUSTIC DEVICES
MAGNETIC RECORDING EQUIPMENT AND COMPONENTS

Division of Clevite Corporation

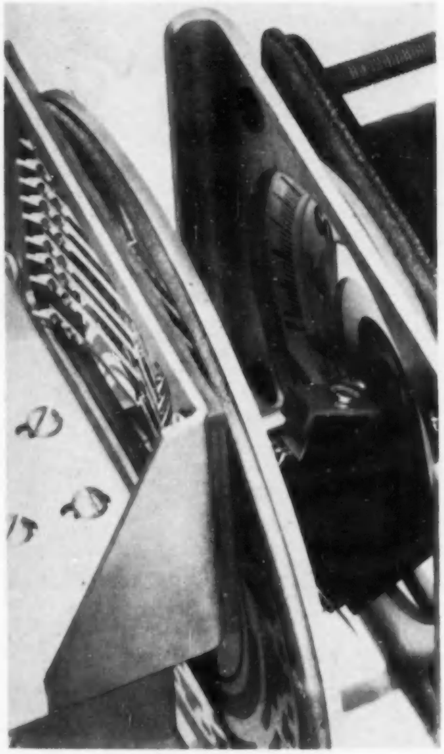


FIG. 1. Scanner, dial being scanned, and code disc and brush assembly.

FIG. 2. Another view of code disc and brush assembly, showing motor.

Reads Meter Optically, Then Digitizes

When the pointer of a meter gets in the way of a light beam directed on a mirror, a code disc sets up a battery of storage relays, recording the disc's position. This, in a nutshell, is the idea behind an amazingly simple analog-to-digital converter.

Long-distance transmission of data representing voltage, current, and power has been markedly improved by conversion of these data into digital form. As digits, the data are invulnerable to varying line conditions and have the accuracy necessary for efficient power distribution system operation.

Conversion of voltage and current has been fairly simple, but not conversion of power to either an analog or digital form suitable for transmission. This has been expensive, inaccurate, complex, and subject to drift, temperature and voltage effects.

Now, however, a new development by the Pacific Div. of Bendix Aviation Corp. assures accurate and inexpensive transmission of digitized readings of these three variables, and many others, too. The development is a photoelectric scanner, which converts an analog meter indication into digital form for serial or parallel long-distance transmission in a simple and quite ingenious way. It uses a conventional pointer-type wattmeter without modification of the movement or loading of the output shaft.

The basic elements of the meter-reader are: 1) a photocell and light source assembly; 2) a mirror about the length and width of the meter's scale; 3) a small motor; 4) a code disc; 5) a sensitive relay; and 6) a group of "storage relays", one for each digit of the code disc.

The small motor continuously rotates the photocell-light assembly and the code disc, as the figures show. Behind the pointer of the meter is the mirror segment. As the light and photocell rotate, the light beam is reflected to the photocell by the mirror, except when the pointer gets in the way. When this happens the sensitive relay drops out and the battery of storage relays is connected to the code disc, assuming self-held positions that correspond to the code disc reading. The storage relays then can be called upon for a parallel or serial digital indication of the meter reading. This digitizing device may be applied to any measurement in which the usual readout is the position of a pointer with respect to a scale. In the case of the Bendix Aviation development described here, digital readings of electrical power may be taken at 3-sec intervals and transmitted with an accuracy of better than 1 per cent over long distances.

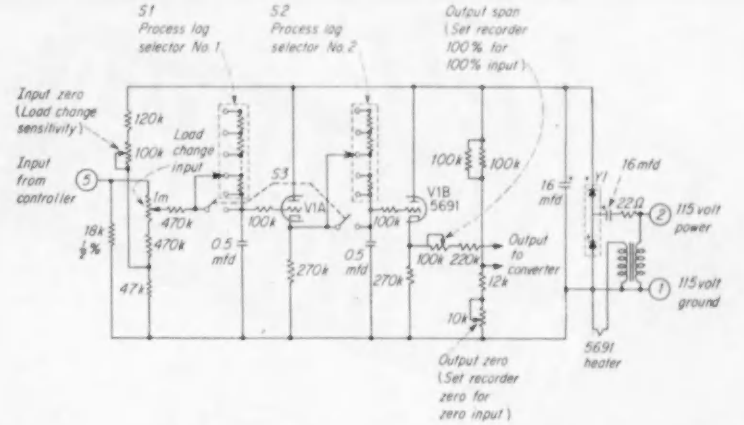


FIG. 1. Process controller with two noninteracting adjustable (switches S1 and S2) lags.

R. G. BRADLEY, The Swartwout Co.

Use Process Analogs to Prove a System

Electronic control systems make possible practical direct analogs of process lags. The approach permits inexpensive system study without computer setup.

Process analogs have many uses in automatic control. They can be substituted in graphic panels for the actual process, and used to test the panel or to train operators in its use. They can be used to teach proper start-up procedures. Component failures can be introduced in controllers for trouble-shooting training.

For an electronic process control system, the process analog offers another practical aid to the control engineer. If the process time constants are known within reasonable limits beforehand, a breadboard model system can be wired up very inexpensively, using stock controllers with the process analogs. In this way, all the operating vagaries of a new system can be experienced and ironed out before the final design and construction of the actual plant. This is a common technique employed in electromechanical servo design.

THE ELECTRONIC PROCESS ANALOG

In their adjustable rate and reset (derivative and integral) circuits, electronic controllers already contain the components needed to represent the time lags found in a process. Figure 1 is a schematic diagram of a two-lag process analog with each lag adjustable, made by modifying some of the circuitry of a process controller. It can also simulate a load change.

This analog is designed to accept the output of a controller as its input. After the time lags are introduced, the output of the analog can be considered as a measured variable and can be fed to a subsequent controller as an input signal. Note that the analog attenuates the signal, using two cathode followers to make the separate lag adjustments independent. This is satisfactory because the controllers are designed to accept the low power outputs of primary element transmitters.

Figure 2 shows a process control system using process analogs like that of Figure 1 to simulate the process lags. The stripper column is simulated by a floating proportional plus reset controller, because only one time lag is needed. The controller is slightly modified. Its output (simulated tank level) will continue to change until the signal (inflow) equals the set point (outflow).

Modifying an electronic controller to make the process analog puts the output immediately in electrical form, eliminating any need for mechanical or pneumatic components in the simulated system. Interconnections between systems are all wire, permitting inexpensive "breadboard" systems.

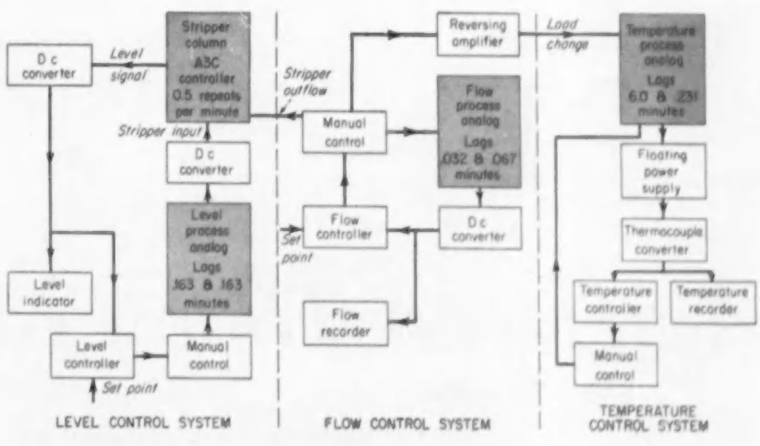


FIG. 2. Block diagram shows how the process analogs can be used.

Spring-powering a Position Servo

This little mechanism offers possibilities as an aircraft component in applications needing a light and forceful position servo for limited-duration control.

RAYMOND N. AUGER

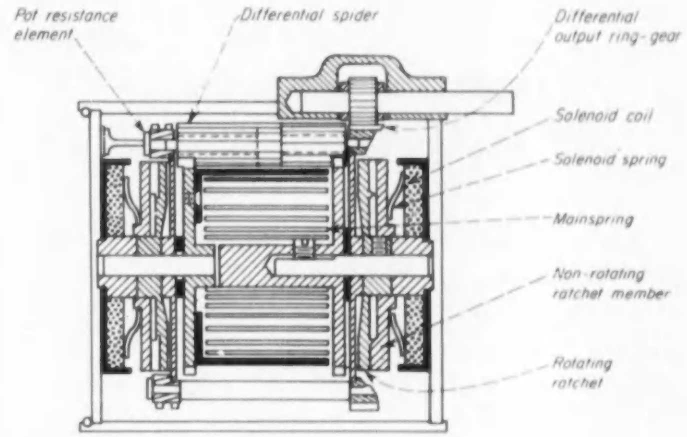
The mechanism on this page is an extension of the principle of the clockwork torque amplifier first described by the author in the January 1955 issue of this magazine. Again, a spring is used as the primary source of energy, and the pawl-and-ratchet control of a differential again provides the means for limiting the amount and direction of output rotation. However, the original model utilized the mechanical displacement of the spider of a comparator differential to operate the pawls of the output differential. This version provides a shaft output proportional to a voltage input by using a potentiometer as an input differential and by using a relay as a comparator.

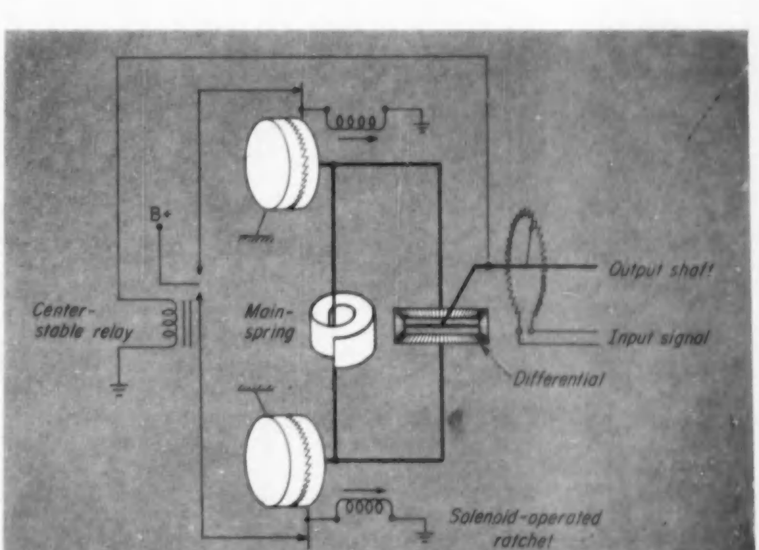
The high-energy, low-inertia possibilities of spring power might make this system eligible for aircraft control situations, especially those requiring a fast and powerful position servo to operate for a limited period of time (on the order of seconds or a few minutes). Designed for as compact an assembly as possible, the version, shown in section above, contains a 1⅛-in.-wide by 1¾-in. (barrel inside diameter) spiral mainspring. The dimensions of the case (which includes everything in the schematic, below, except the control relay) are 3¼ in. long by 3⅛ in. in diameter. Inasmuch as this design does not include a self-winding mechanism, mainspring energization is accomplished through the output shaft. As with the original all-mechanical servo, backlash in the gearing of the output differential has no effect on the accuracy of the output, since all the meshes are involved in the same direction of rotation. The only mesh that can introduce backlash into the output is the last one, which drives the output shaft. If the instrument is to operate a control cable, this mesh can be eliminated by mounting a cable sheave in place of the differential's ring gear.

THE CONTROL RELAY

The schematic shows how the pot on the output shaft divides the input signal to operate the control relay. The centerstable relay arrangement shown is polarity sensitive. This means that when the output is at 180 deg, the input will be as high above ground as it is below. As the low (negative) side of the signal rises, the relay detects the current and its direction, operating the proper solenoid to rotate the output shaft to null out any voltage across the relay.

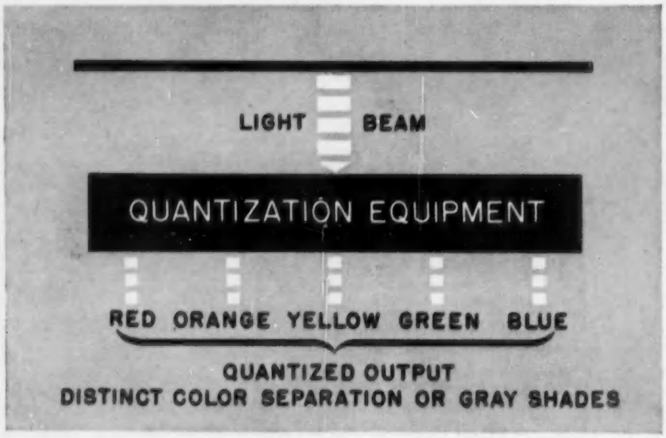
Another relay comparator circuit that can be used in place of the foregoing one operates in a manner analogous to a conventional on-off contactor servo, but does not have the hunting inherent in such a device. This second system uses two relays, in series or parallel, each having spdt contacts. These can be wired so that: 1) when the error signal is below a given voltage, both relays are in an





FORD INSTRUMENT QUANTIZES LIGHT

Colored lines or spots on a piece of paper can become a means of conveying information – Rorschach charts, impressionist paintings and survey maps are all visual message carriers. Ford Instrument engineers found it necessary to translate such color information into electrical or mechanical quantities, (quantization) with less distortion than is inherent in the usual photographic techniques. Such quantities can in turn be used as signals that actuate computers, make offset plates, and generally put to use the information implied by the difference between the colors or the distribution of the colors.



The quantization performed by Ford is not restricted to color alone. For example, a black and white photograph represents an aggregate of light and dark areas of varying shades, and this display must frequently be converted into continuous or discrete electrical quantities for various purposes and uses. Ford engineers recently developed equipment which can quantize and record the various degrees of color, or gray areas in photographic negatives, and to correlate this information into usable data. This equipment was developed for a classified project – the equipment is unavailable for general use – however the technical know-how gained by Ford – combined with Ford's superior production and engineering facilities – is available in the creation of light quantizing equipment for you.

Light quantizing is but one of the many facets of Ford Instrument design and development. For more information about Ford's products, services and facilities, write for an illustrated folder. Ford engineers will be happy to discuss your problems of control with you.

88

FORD INSTRUMENT COMPANY

DIVISION OF SPERRY RAND CORPORATION

31-10 Thomson Avenue, Long Island City 1, New York

Beverly Hills, Cal. • Dayton, Ohio

Ford's capabilities are among the finest in the country

Three dimensional cams are used in elaborate computing devices to characterize shell ballistics, magnetic variation, or to solve some basic mathematical function. Precision in 3-D cams is of vital importance. Ford Instrument designed and built a unique machine that can produce extremely accurate cams from a skillfully made master. As many as two thousand data points are end-milled to set precisely the contours of the handcut masters.

Equipment used for defense must undergo rigorous tests for accuracy and dependability in combat. At Ford, environmental testing laboratories reproduce extremes of desert or arctic battle, shock of warship broadside, salt fogs and heavy seas. When flaws have been detected and corrected, equipment is okayed for volume production and use throughout the armed services.

Typical of Ford Instrument's 40 years of experience in precision control is its work in the field of nuclear power. The Company, for example, is building the control rod drive mechanism for the Seawolf, second atomic submarine. Reactor designs, sensing mechanisms, control equipment and systems, nuclear calculations, and other specialized equipment and abilities are offered by the Company to this expanding industry.

unenergized position, and one of the ratchets is released; 2) when the voltage of the error signal is above a given level, both relays are energized and the other ratchet is released; 3) when the voltage is in a narrow "dead zone", one relay is energized and the other unenergized, and neither ratchet is released. This latter condition produces a narrow zone of "zero error". Needless to say, it cannot be narrower than the error represented by the space between ratchet teeth. The system is polarity insensitive, and could even operate on an ac control signal.

Speed of response is limited by the time required for the pawl to engage the ratchet. If there are 100 teeth per output revolution (therefore 1 per cent possible error), and the output is revolving at 1 rps, the time between possible teeth engagement is 10 millisec. As the inertia of the pawl and the force of the spring moving it should enable at least 0.020 in. travel (the depth of a ratchet tooth) in 3 millisec, a speed of 3 rps would appear to be near the maximum allowable. However, the low inertia of the rotating members should allow this maximum angular velocity to be attained within a few milliseconds. If the friction or inertia of the load is not enough to hold the output within the 3-rps limit, a door-bell-like contactor arrangement on the ratchet, as shown in the schematic, can be added to slow it down.

The power gain of the system can be quite high if used with the proper preamplifier. A single power transistor can control enough current to operate miniature relays, which in turn will operate the solenoids to release the stored energy in the spring.

Getting High Torque from a Synchronous Drive

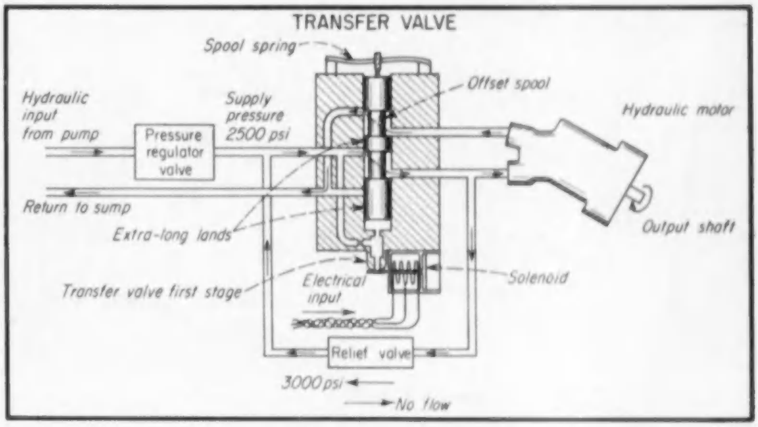


FIG. 1. Hydraulic flow schematic of the antenna spin drive.

A. C. MORSE, Convair, San Diego

An electronic-hydraulic speed control system for spin stabilizing an airborne radar antenna effectively simulates a synchronous motor with extremely good lock-in torque characteristics and produces impressive operating figures. The unit holds antenna rotational speed constant with respect to the earth, regardless of what the aircraft does, by using a yaw rate signal to vary the input frequency to the synchronous antenna drive.

The antenna needs rotate in one direction only. The transfer valve spool (Figure 1) is displaced mechanically so that the oil flow required for synchronous speed occurs at zero input current. This produces the flow characteristic shown in Figure 2. Two extra-long lands on the spool assure unidirectional flow.

A SYNCHRONOUS MOTOR

The spin drive uses a constant displacement hydraulic motor of the piston swash-plate type, geared to the radar antenna. Speed control is achieved through the hydraulic transfer valve, in series with the motor. A magnetic pickup counts the teeth of a gear on the motor output shaft and supplies an alternating current whose frequency is proportional to the speed of the antenna. This alternating current is compared with a standard frequency in two ways, (see block diagram in Figure 3, next page).

One comparator measures the difference in frequency between the feedback pickup and the frequency standard, furnishing an error signal that brings the antenna up to speed. Then, when the frequency error is within one cycle per sec, a phase comparator takes over. The error signal from this latter comparator is proportional to the difference in phase angle between the feedback and reference signals. In effect, then, one gear tooth can be locked on one cycle of the reference frequency, and the result is the equivalent of a synchronous motor.

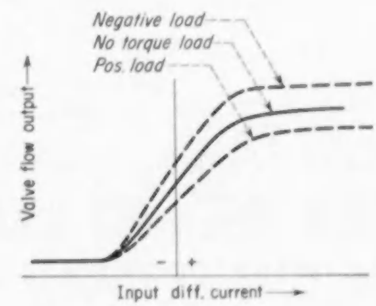


FIG. 2 Transfer valve flow curve.

The valve's equation is developed as follows: the usual orifice flow equation is taken as

$$Q = CA\sqrt{\Delta P}$$

where Q equals volume flow, A orifice area, ΔP pressure drop across the orifice, and c orifice constant. Then the transfer valve's equation may be stated as

$$Q_L = ci\sqrt{\Delta P_v} = ci\sqrt{P_s - \Delta P_L}$$

where i equals control current, c valve constant, P_s supply pressure, ΔP_v drop across valve, ΔP_L drop across load, and Q_L flows through load (motor).

Construction—Snap action contacts, totally enclosed, extra insulated terminals for terminal board use. This relay is available in a variety of mountings, operates in any position, and may be mounted on a grounded surface without additional insulation. Standard contact arrangement is single pole normally closed. Can furnish single pole double throw where extra normally open contact is required.

Operation—When power is applied to the motor a voltage is generated in the motor phase winding by the run winding as the motor accelerates in speed. The relay coil in parallel with the phase winding has the generated voltage of the phase winding across its terminals. When this voltage reaches a predetermined value . . . corresponding to the speed at which the phase winding can be disconnected . . . the relay picks up, opening the relay contacts and disconnecting the phase winding from the line.

Application—R-B-M Potential Type Motor Starting Relays are used to start single phase capacitor type motors where it is impractical or impossible to use a centrifugal switch. Such applications as hermetically sealed refrigeration and air conditioning motors, garbage disposal units and deep well submersible pump motors usually require relays of this type.

ENGINEERING DATA

Specifications	Potential Motor Starting Relay 91255 Type
Contact Forms Available	S.P.N.C., S.P.D.T.
Contact Current Rating	35 Amps. Max. Locked Rotor Start Winding Current
Contact H.P. Rating	3 H.P. Max.-N.O. Contact Rated 1½ H.P.-230 Volts
Contact Material	Silver Alloy or Tungsten
Continuous Coil Volts	Up to 500 V.
Underwriters and C.S.A. Status UL File Nos. SA1984 and E12139 CSA File No. LR 13360	Component Approval. Must be approved on Specific Application.
Life Expectancy	250,000 Operations

For characteristics other than the above, please consult the factory.

OTHER PRODUCTS
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R·B·M ®

RBM DIVISION

ESSEX WIRE CORPORATION, *Logansport, Indiana*

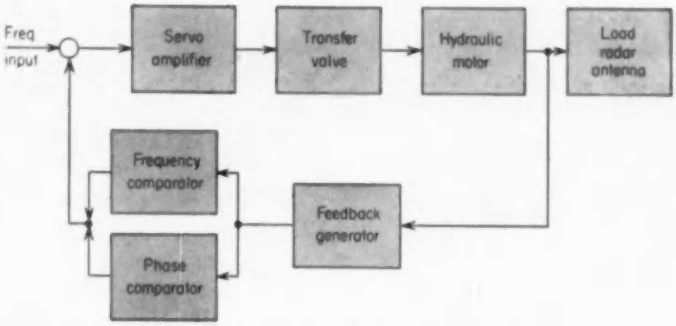


FIG. 3. Block diagram of the antenna's hydraulic spin drive.

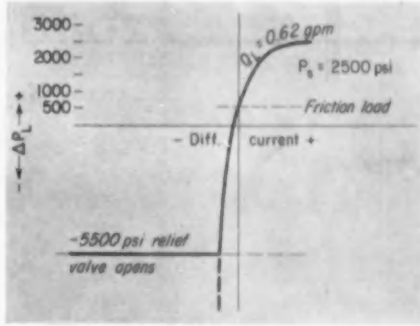


FIG. 4. Pressure control characteristic of the transfer valve.

The valve is controlled to hold Q_L constant regardless of torque disturbances. Therefore, the curve of load pressure drop vs. current (Figure 4) is an exponential with the zero current point occurring at the value of the load pressure drop that is necessary to overcome friction torque. If a high negative current signal is applied as a transient or at a fast rate, ΔP_L goes to a very high negative value.

PRESSURE RELIEF

As finally designed, the system permitted this maximum negative pressure to reach the 2,500 psi supply pressure plus 3,000 psi cracking pressure, for a grand total of 5,500 psi. This design was necessitated by the flow characteristics and pressure control characteristics of the transfer valve, the second a direct result of the first.

Here was the problem: If the transfer valve were suddenly closed, the motor would act as a pump, and the compressed oil would cause the pressure on the outlet side to rise until one of three things happened: something broke, the transfer valve opened, or the high pressure was relieved. The obvious choice was to relieve the pressure, and this was done with a relief valve.

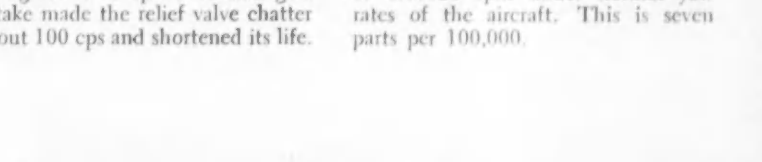
At first the relief valve was shunted across the motor ports, but it was found that when the antenna's rotation was rapidly decreased, the load pressure leaped above the cracking pressure and the relief valve opened, permitting the load to continue overspeeding. This called for a continuous error signal. And after the pressure was sufficiently relieved, the relief valve, having reseated, would bounce open again. The speed of this give and take made the relief valve chatter at about 100 cps and shortened its life.

The alternative that was adopted was to shift the relief valve's outlet to the pressure line, where it appears in Figure 1. Still another method would be to place a mechanical stop on the transfer valve spool so that the valve could never close completely. The minimum opening could be set to give the maximum required decelerating torque at synchronous speed. Then the relief valve is not needed.

OPERATION

Speed control was found to have a maximum error of plus or minus 0.07 cps, or plus or minus 25 deg phase angle, with a 1,000 cps reference frequency. With 250 gear teeth on the reference gear, the antenna's revolution speed would be 240 rpm and the maximum error would be 0.07 x 250 or 0.00028 rpm under normal yaw rates of the aircraft. This is seven parts per 100,000.

Frequency Response Slide Rule Improved



The frequency response slide rule was invented by Keisuke Izawa at the Tokyo Institute of Technology. In its original form (see CONTROL ENGINEERING, September 1954, page 85) it was designed to solve expressions like:

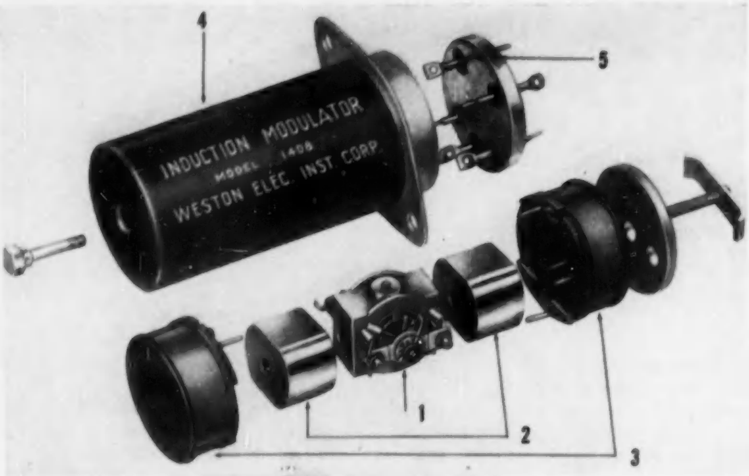
$$G(s) = Ks^h \frac{(\tau_{a1}s+1)\cdots(\tau_{an}s+1)}{(\tau_{b1}s+1)\cdots(\tau_{bn}s+1)} e^{-Ls}$$

where K is the gain constant, h (positive or negative integer) is the number of differentiations or integrations, s equals $j\omega$, τ and L are positive constants, τ_a's are lead time constants, τ_b's are lag time constants, and L is the dead time of the system.

Second-order terms of the form $(\tau^2s^2 + 2\zeta\tau s + 1)$ had to be factored into terms like those above to be solvable on the slide rule. Mr. Izawa and Tomoaki Morinaga have designed a transparent lucite attachment for the slide rule that permits direct handling of second-order terms. The attachment makes it possible also to calculate the closed-loop magnitude ratio in decibels and the phase response angle in degrees directly on the slide rule. Formerly, this had to be done by referring the open-loop response to a set of two nomograms.

(**In answer** to many queries: The slide **rule is made** by Hemmi Bamboo Slide Rule **Mfg. Co.**, Japan, and is distributed in the **United** States by Frederick Post & Co., Chicago—Ed.)

NEW PRODUCTS



LISTING IN GROUPS

MODULATOR AMPLIFIES DC, alternates it up to 1,000 cps.

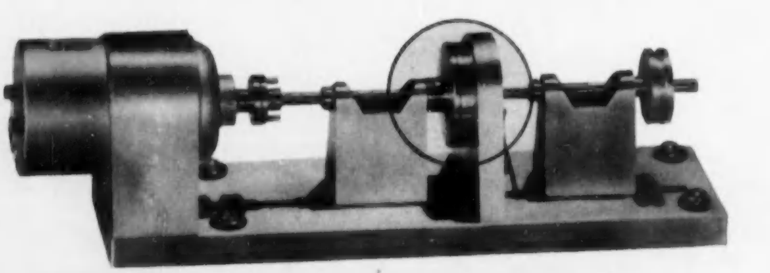
The uniquely constructed modulator shown here operates roughly like a differential transformer. Minimum signal current of 30 microamps results in the maximum deflection of a movable coil in the field of a coil energized at the modulating frequency. Maximum open circuit output from the movable coil is 1.9 volts with a field excitation of 115 volts 400 cps. Linearity between the amplitude of input dc and output ac is 2½ per cent, says the maker. If the 100 deg swing of the movable coil is limited to 80 deg, linearity to within 1½ per cent is possible.

Two of the device's most important features are its contactless operation and its actual signal power gain of 28 db. It may also be used as a function multiplier, as field coil excitation and signal coil deflection current are multiplied at the output. Since the movable coil has no frame, the modulator has no inherent damping except the negligible amount provided by air. However, damping can be achieved to meet requirements by placing a shunt resistor in the output circuit. A shunt of ¼ the resistance of the movable coal produces an overdamped condition with a response time of 0.5 sec. for 62.8 per cent of full scale deflection.

A capacitor helps put output voltage in phase with input voltage.

The little device is 2.4 in. long and 1.1 in. in diam and weighs 5 oz. It's made rugged enough for airborne use. *Weston Electrical Instrument Corp., Newark 5, N. J.*

Circle No. 1 on reply card



MAGNETIC CLUTCH toggels magnetically for impulse operation by polarized signals.

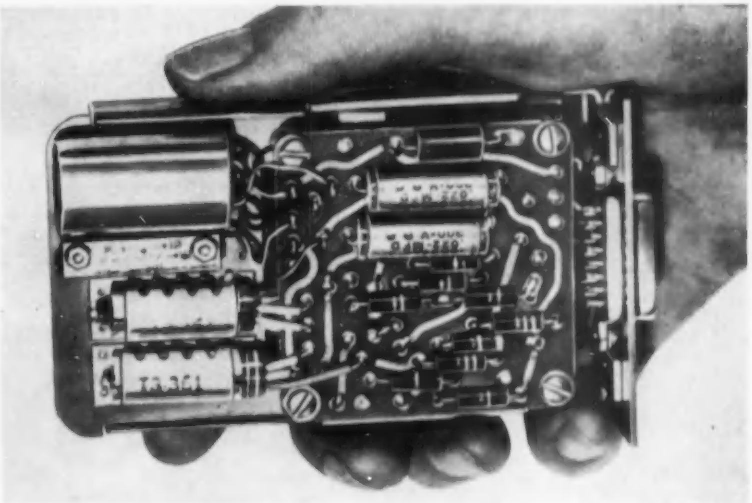
Maybe your New Product editor has magnetic clutches too much on his mind; nevertheless, this particular clutch looks like the ingenious product of the month.

Here's the way it works: A permanent magnet disc "floats" between the driven disc and a stationary electromagnet. When the electromagnet is energized and the polarity of the electromagnetic field is the same as the permanent magnet, the pm is repelled towards the driven disc, which it then grabs. Now the current in the electromagnet can be turned off, and the clutch remains engaged. As there is an air gap between the coil and the pm, friction heat, which might result from slipping, is not directly transmitted to the windings of the electromagnet, nor is any heat from an energized coil present. To disengage the clutch, another impulse is sent to the electromagnet, this time setting up a magnetic field of opposite polarity to that of the permanent magnet. This field is powerful enough to pull the pm away from the driven disc. Again the electromagnet can be de-energized, and the permanent magnet remains attracted to the core of the electromagnet rather than the driven disc.

While this design has the disadvantage of not allowing proportional control of torque through some linear range, a proportional effect may be obtainable by a "jitter" ac signal of the right frequency. *Locke Machine Co., 971 E. 63rd St., Cleveland, Ohio.*

Circle No. 2 on reply card

AMPLIFICATION, summation, isolation, temperature transmission, handled by plug-ins.



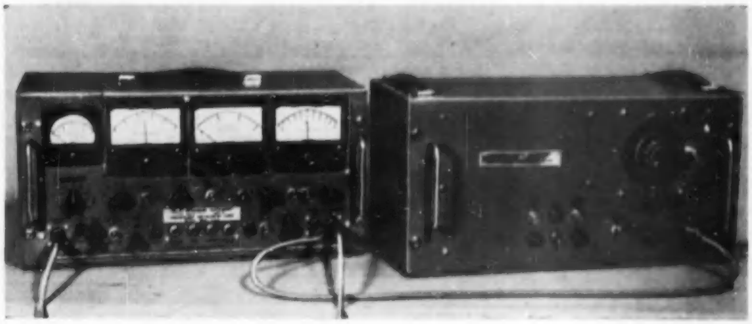
Among the items to be seen this month at the IRE show, Booth No. 309, is a temperature measuring system made in the neat form shown here Platinum resistance elements in a variety of configurations provide fast-response inputs for temperature ranges as narrow as 25 deg C within a range of minus 100 to plus 600 deg C, and as wide as that entire range. Output is 0 to 5 volts, with resolution to within 1 deg C. The 100 ohms max output impedance enables a standard 1 ma recorder to be driven directly, or the amplifier can be used with telemetering commutators.

Also built into plug-in containers are a servo amplifier, summing amplifier, and isolation amplifier. The servo amplifier's output is 100 milliwatts. The summing amplifier will accept up to 14 channels of 400-cycle current, isolating each better than 60 db, and vectorially adding them to within 2½ per cent accuracy. Voltage gain is adjustable between 4 and 40.

The isolation amplifier's gain is from 1 to 70 with 100 milliwatts power output. *Rheem Mfg. Co., Gov. Products Div., 9136 E. Hall Road, Downey, Calif.*

Circle No. 3 on reply card

ENVELOPE DELAY meter for system transmission delays.



The apparatus seen here measures transmission delay of various frequencies in data transmission lines and systems.

The output frequency of the generator can be manually set or automatically swept through any portion of the 200 to 10,000 cps band, at speeds from ½ to 4 rpm. Output power is adjustable from 10 db above to 10 db below 1 milliwatt in a 600-ohm line. The receiving point can be located anywhere in the system under test. Synchronization means for the sweep rate are built into the receiver, which gives direct reading of transmission delays up to 20 ms. Longer delays are also readable but with less accuracy. *Acton Laboratories, Acton, Mass.*

Circle No. 4 on reply card

LOW-PRICED dc computer has function generator, fast time, and automatic stabilization.

The Weber General Purpose Analog Computer is said to be the only device in its price range to be complete within one basic unit. Furthermore, says the maker, the average secretary can be trained to operate the machine within 8 hrs.

No auxiliary equipment is needed to present dynamic solutions in acoustics, aerodynamics, vibration, thermodynamics, structures, and chemistry. The computer can solve twelfth-order linear differential equations and non-linear equations.

Inside the desk-sized machine one finds 12 integrating/summation stabilized amplifiers, 12 summation stabilized amplifiers, 36 scale pots, at 1 to plus or minus 100-volt reference voltage power supply, one eight-line-seg-

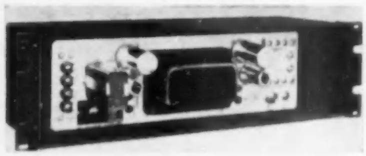
ment function generator, 24 individual overload indicators, one pre-patch panel, a readout system consisting of a 6-in. meter with mirrored scale and readable accuracy of 1 per cent, and a 5-in. dual beam cathode ray oscillograph.

The maker claims this is the only general-purpose machine in its price range to offer both real and fast-time problem solution. In fast-time, the speed of the problem is increased 50 times. A hold switch stops the solution at any point.

Among the machine's interesting features is an Auto-Stabilizing system that automatically sets each amplifier at zero before the start of real-time problems. To simplify setting up problems of a standard type, factory-fabricated General Purpose Problem Boards are available. With these, switch positions and knob settings introduce the values without recourse to the standard patchcords setup. *Weber Aircraft Corp., 2820 Ontario St., Burbank, Calif.*

Circle No. 5 on reply card

INDICATORS, AMPLIFIERS, CONTROLLERS



TRANSMITTING potentiometer for low-level pickups.

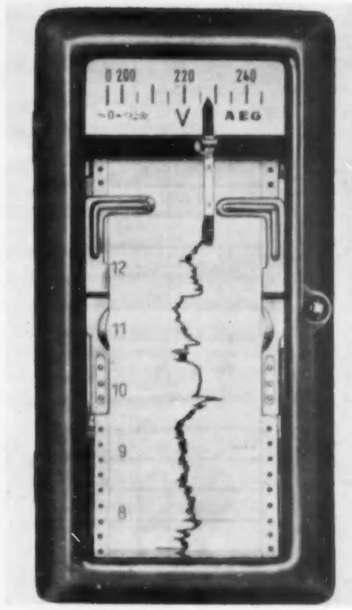
Said to be based on entirely new principles, a new transmitting potentiometer converts a few microvolts input into a 6- to 50-millivolt output. The device is intended for increasing the low power signals of thermocouple pickups or other low-output transducers to a level that can be transmitted substantial distances. The instrument uses no slidewires, batteries, standard cells, choppers, or converters. The company's Microsen balance is said to enable the potentiometer to perform with only two tubes. *Industrial Controls Div. of Manning, Maxwell & Moore, Inc., Stratford, Conn.*

Circle No. 6 on reply card

NEW PRODUCTS

MAGNETIC SERVO AMPLIFIERS: A line of magnetic servo amplifiers requiring no dc power sources drives 400 cps two-phase servo motors draining up to 40 watts. Control signals can be ac or dc. *Timely Instruments & Controls Corp.*, 1645 W. 135*th St., Gardena, Calif.*

Circle No. 7 on reply card



MINIATURE recorder available in portable models.

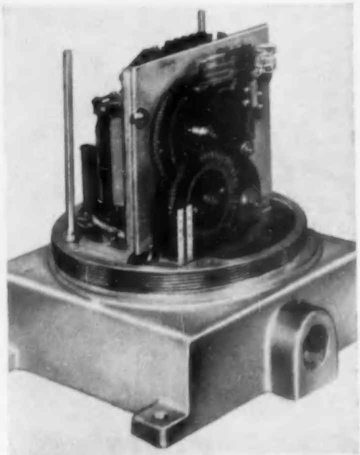
A line of imported miniature recorders has electric or ink chart marking and 8- or 32-day clock motor or synchronous motor drives. Full deflection inputs range from 1 ma to 6 amps or 10 volts to 600 volts. Consumption is as low as 3 milliwatts. The RK 5, made by AEG, is about 7½ in. tall and 3½ in. wide; its visible chart area is 2 by 4 in. Rectangular co-ordinate paper is used. Various gear combinations provide various chart speeds. *International Sales & Engineering Corp.*, P. O. Box 281, *Wilmington 99, Del.*

Circle No. 8 on reply card

COLOR MONITOR: Wavelength absorption from a continuous flow of materials or finished products enables a new color-sensing instrument to provide visual or audible warning of product deviation from prescribed bands.

Observations may be made through the range of ultraviolet to infrared. A 50-millivolt proportional output is the means for direct process control. The Spectrostat can simultaneously monitor two factors, such as color and turbidity. *Kaye Development Co., South Norwalk, Conn.*

Circle No. 9 on reply card



MEASURING SYSTEM used for control.

The instrument shown here is intended for use in place of the transmitting element of a remote gaging system. Instead of transmitting a reading to the operator on receipt of a readout signal, this device does something to the process, such as operate a group of relays. When called, the station responds with an identifying signal. *Shand & Jurs Co., Berkeley 10, Calif.*

Circle No. 10 on reply card

LOW LEVEL MAGNETIC AMPLIFIER: The new R6A5MI operates on standard 115 vac line current, with low current detectors such as thermocouples, strain gages, photo tubes, or crystal detectors. It will provide push-pull dc output for a reversible polarity dc input signal. It's rated for a dc output of 5 milliwatts in a resistive load of 600 ohms when stimulated by a 300-microamp input. The input impedance is 1,000 ohms, and the time constant 0.1 sec for 63 per cent of response. Input impedance is variable between 100 and 8,000 ohms. *Polytechnic Research & Development Co., Inc., 202 Tillary St., Brooklyn 1, N. Y.*

Circle No. 11 on reply card


For
ACCURATE HIGH SPEED SWITCHING..
Specify
ELECTRO TEC
miniature ultra-low torque
Precision
Selector Switch
• Withstands Shock and Vibration
• Offers High Accuracy Measurement
• Operates at High Speeds
This new Electro Tec Precision Selector Switch is ideal where miniature size, low friction torque, high accuracy, and low electrical noise at high speeds are requirements. Simplified circuits and long service life recommend it for a wide variety of uses including sampling, pulse generation for precision measurement, telemetering and strain gage applications, in aircraft, missiles, servos, computors, etc. Switch design incorporates many exclusive features that have gained industry-wide acclaim for Electro Tec precision slip rings, commutators and brush blocks.
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CALL OR WRITE
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8 or 10 position switches in standard size 10 synchro housings are available for immediate delivery; other circuit combinations supplied to specifications.
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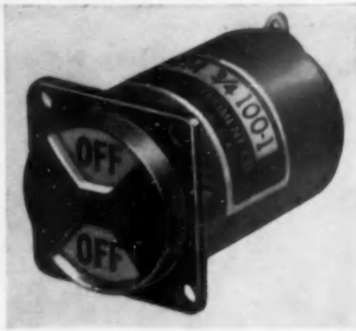
NEW PRODUCTS



MINIATURE INDICATOR only ¾ in. in diam.

The little indicator shown above provides clear-cut display of the function it supervises. Behind-panel-depth is only 1¼ in. Operation of the display is by conventional moving-coil dc meter movement. *Marion Electrical Instrument Co., Greiner Field, Manchester, N. H.*

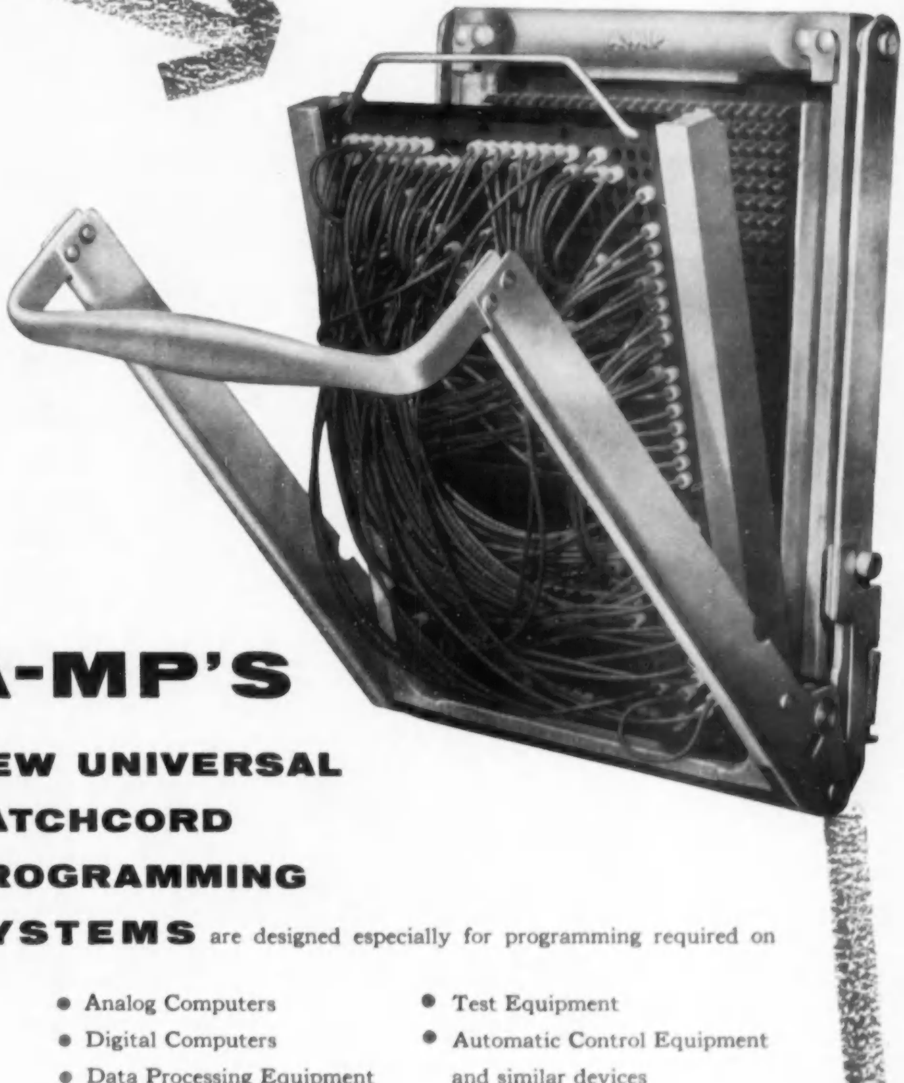
Circle No. 12 on reply card

FLOW TRANSDUCERS: Said to be accurate to within ½ per cent, a revised line of strain gage flow transducers is available in from ¼ to 1 in. AN sizes. It's sensitive to flow in either direction, but for the stated accuracy, the unit must be used through $\frac{1}{10}$ of the range of 0.2 to 125 gpm. *Ramapo Engineering Co., Riverdale, N. J.*

Circle No. 13 on reply card

TRANSISTOR TEST SET: Rapid measurement of transistor characteristics at any frequency from 100 cps to 1 megacycle is the object of model GP4. *Baird Associates, Inc., Cambridge 38, Mass.*

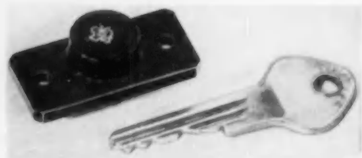
Circle No. 14 on reply card



NEW PRODUCTS

WIDE BAND AMPLIFIER: A new feedback stabilized wideband amplifier, designed to amplify the fast pulses encountered in nuclear research, has a bandwidth from 2,000 cycles to 10 mc. Gain is continuously adjustable to 60 db at 50 volts into a 1,500-ohm load. A 5- to 50-volt fast pulse height discriminator is included. *Electrical & Physical Instrument Corp., 42-19 27th St., Long Island City 1, N. Y.*

Circle No. 15 on reply card



TRANSISTOR dissipates 3.5 watts at 100 deg C.

Said to be ideally suited for servo amplifiers, Type 970 silicon power transistor dissipates 8.75 watts at 25 deg C and 3.5 watts at 100 deg C. Power gain is 18 db at 2.5 watt output, class B operation. *Texas Instruments, Inc., 6000 Lemmon Ave., Dallas 9, Tex.*

Circle No. 16 on reply card

PRESSURE INDICATOR-CONTROLLER: Designed to control pressure ranges as low as 0 to 0.2 in. of water is a new indicator-controller that uses a free-floating slack type diaphragm for ranges up to 6 in. of water differential or atmospheric. *Johnson Service Co., Milwaukee 1, Wis.*

Circle No. 17 on reply card

DETECTORS AND ANALYZERS

TRANSFER FUNCTION ANALYZER: A new English product, consisting of a low frequency decade oscillator and a low frequency phase sensitive voltmeter, is offered to servo systems designers for the rapid construction of Nyquist diagrams. Frequency range is 0.1 cycles to 1 kc. The indicators are accurate to within plus or minus 3 per cent. Four phases of the output of the oscillator, controlled

within 3 per cent, are fed to the phase sensitive voltmeter along with the output of the system under test. Readings of in-phase and quadrature voltages can be plotted directly on squared graph paper to yield Nyquist diagrams. *Solartron Electronic Group, Ltd., Thames Ditton, Surrey, England.*

Circle No. 18 on reply card

HIGH PRESSURE SENSOR: A new automatic beam balance is offered to instrument makers for making measurements in the pressure range above that handled by conventional barometer or manometer, i.e., 100 in. of mercury. *Ideal-Aerosmith, Inc., 12909 S. Cerise Ave., Hawthorne, Calif.*

Circle No. 19 on reply card

PRESSURE TRANSDUCER: Model P-1 pressure transducer takes in the range from ¼ to 100 psi gage or differential. In differential service the maximum line pressure rating is 500 psi. Accuracy rating is within 1 per cent full scale. Instead of resistance elements or differential transformers, this device uses variations in magnetic reluctance to vary its output. *Pace Engineering Co., 6914 Beck Ave., North Hollywood, Calif.*

Circle No. 20 on reply card

COLOR SENSOR'S sensitivity exceeds human eye's.

Measurement of color transmittance and reflectance within 0.0001 reflectance units is simplified through the numerical display calibrated in 0.0002 reflectance units. Model IV makes a complete set of color measurements within 30 sec. For ideas on the use of this instrument in process control, see *Color Basics for the Control Engineer*, CONTROL ENGINEERING, October and November 1955. *Manufacturers Engineering & Equipment Corp., Hatboro, Pa.*

Circle No. 21 on reply card

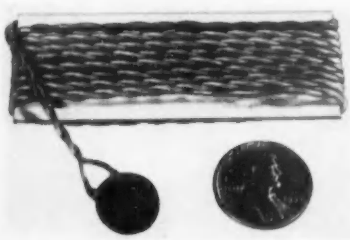
CONTACTOR TACHOMETER: A new tachometer indicator has high-low contactors for the actuation of

alarms or control functions. It's sold with any one of 48 different scales. *Metron Instrument Co., 432 Lincoln St., Denver 3, Colo.*

Circle No. 22 on reply card

DISPLACEMENT TRANSDUCER: The linear (really *lineal*) Inductosyn, able to sense a variety of machine tool carriage movements, consists of a pair of glass plates with etched lines. The inductive effects of these etched lines as they move by one another provide information on the movements of tool parts for a digitally programmed controller, also available. Attached to a milling machine, the control system yields an automatically programmed jig borer. *Farrand Controls Inc., 4401 Bronx Blvd., New York 70, N. Y.*

Circle No. 23 on reply card



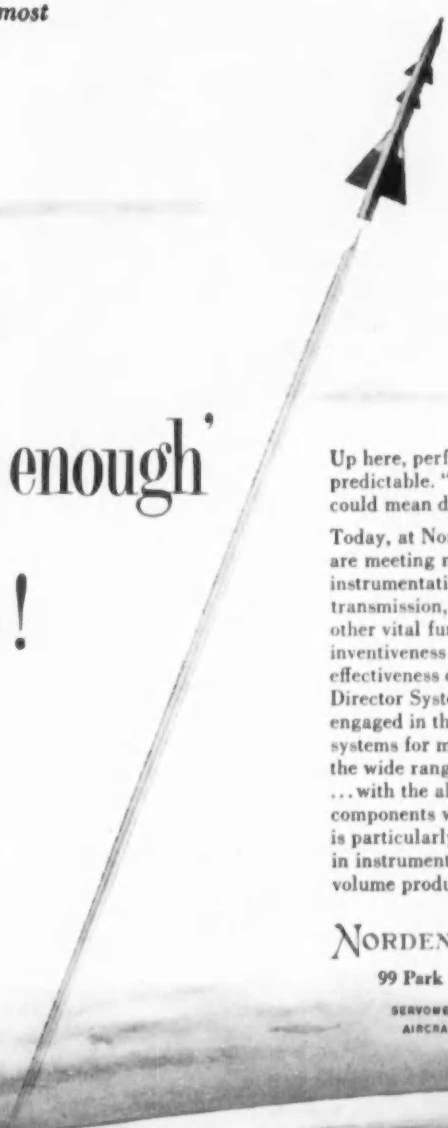
HEAT FLOW detector has high output, sensitivity.

Made of a special tellurium alloy, the penny-sized disc shown here is said to be so sensitive that a heat flow of 1 Btu per sq ft per hr generates 2.5 microvolts. Internal impedance is 1 ohm and thermal resistance is 0.009 deg F per Btu per hr per sq ft. Besides its applications in control, the tiny unit has use in the measurement of thermal conductivity, as it can be placed in conducting bodies. *National Instrument Laboratories, Inc., 6108 Rhode Island Ave., Riverdale, Md.*

Circle No. 24 on reply card

LOW PRESSURE SWITCH: A new low pressure switch is designed for use with very low vacuums where regulation is required in inches of water column. It can be adjusted to provide operating differentials of 0.1 in. of water column. *The Henry G. Dietz Co., 12-16 Astoria Blvd., Long Island City 2, N. Y.*

Circle No. 25 on reply card



This picture of southwestern U. S. and Mexico is an official United States Navy photograph made from the research rocket, Viking 12, at an altitude of 143.4 miles.

NEW PRODUCTS

ACCELEROMETER'S linearity is to within 2 per cent.

Designated the Model GG22 series, a new line of linear accelerometers senses positive or negative accelerations in either the vertical or horizontal planes. The series runs from plus or minus 0.5 to more than 50 g's. Threshold can be made under 0.009 g. Power for the hermetically sealed units is 20 vdc. Size is 3.255 by 2.320 in. in diam. Doelcam Div. of Minneapolis-Honeywell Regulator Co., 1400 Soldiers Field Rd., Boston 35, Mass.

Circle No. 26 on reply card

PRESSURE PICKUP survives blasts, hears voices.

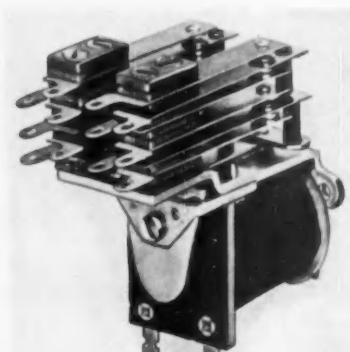
Sensitive enough to detect the pressure waves generated by the human voice, a new Swiss-made pressure pickup is also said to be rugged enough to live through rocket engine explosions that demolish associated parts.

It's used to study the effects of ignition, combustion, port action, etc., on cylinder pressure in gasoline engines, but the pickup requires no cooling, says the maker. Its initial calibration is said to last its life. With a high pressure adapter, the pickup's normal range of 0.1 to 3,000 psi can be upped to 20,000 psi. An unusually high output of over 500 volts (measured with an electrostatic voltmeter) means that it requires a minimum of amplification to operate a dc oscilloscope.

The pickup uses a composite diaphragm consisting of a corrugated soft outer ring with a stiff inner section, in somewhat the way that loudspeakers are constructed. Sensitive element is a quartz crystal with a linear output. Also shown in the photo with the 2-in. long pickup is the Piezo-Calibrator, a variable calibration source containing its own mercury batteries and a meter for accurately measuring the pickup's output. The calibrator's output impedance matches the input of dc oscilloscopes. *Kistler Instrument Co., 2446 Pierce Ave., Niagara Falls, N. Y.*

Circle No. 27 on reply card

RELAYS AND SWITCHES



TINY RELAY'S 5-amp contacts have flexible arrangements.

Model CRU relay features a wide choice of contact arrangements and, despite its small size, 5 amps in each contact. Coils for ac or dc, and many voltages are stocked. *Ohmite Mfg Co., 3683 Howard St., Skokie, Ill.*

Circle No. 28 on reply card

"This Is What I Want in a Potentiometer"

1 **Versatility**—A potentiometer to meet a wide field of applications without additional design changes.

2 **Permanent Accuracy**—Resistance element integrally molded within the housing. All leads, taps and terminals firmly encapsulated, permanently locked in place.

3 **Long Life**—Rigid, fixed lead screw to guide contact over resistance element.

4 **Dependability**—A potentiometer that possesses excellent mechanical and electrical stability under extreme environmental conditions.

5 **Absolute Linearity**—A potentiometer with linearity built into it. I don't want to hunt for linearity by trimming.

6 **Specifications**—It must meet my rigid commercial and/or military equipment requirements.

7 **Availability**—I want the model that fits my needs readily available in production quantities.

BORG 900 SERIES MICROPOTS

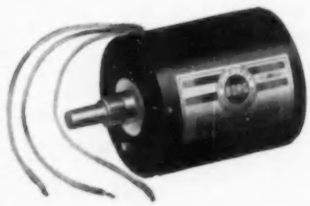
Meet All These Requirements

"It's tops!", that's what design engineers everywhere are saying about the Borg 900 Series Micropots. To meet the tremendous demand Borg has geared production to new high levels assuring you fast delivery of any model in any quantity. All 48 models are available now!

It's no wonder that these pots have had such a tremendous reception for they are truly the "New Standard of Precision Potentiometers". Let us send you engineering data and name of your nearest Borg "Tech-Rep". Write today.

BORG 1100 SERIES MICROPOTS

A precision 10-turn potentiometer that offers your products a price advantage in today's competitive markets. Engineered for easy installation with 9 inch coded leads. Accurate, dependable, long lived.



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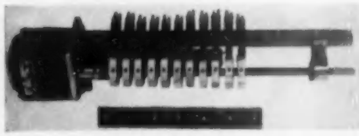
COMPLETE INFORMATION
Ask for Catalog No. BED-A158

BORG EQUIPMENT DIVISION
THE GEORGE W. BORG CORPORATION
JANESVILLE, WISCONSIN

NEW PRODUCTS

SENSITIVE RELAY: An unusual mechanical design is said to be responsible for a 15 per cent increase of winding space in a new low-cost sensitive relay. Sensitivity is 40 mw. Coils are supplied with resistances up to 22,000 ohms. The higher contact pressure of the new design is said to enable the relay to resist shocks of up to 25 g. It weighs only 1⅛ oz. *Sterling Engineering, Princeton, Ind.*

Circle No. 29 on reply card



CAMMED interrupter provides pulses with accuracy.

Driven at speeds from 1 through 15 rpm or faster, the arrangement seen here uses specially cut nylon cams to operate leaf-type springs according to any desired pattern. Guaranteed maximum error between points on any one cam is 1.5 deg, and between points on any two cams, 2.25 deg. Seven switch pile-ups are available. *Holtzer-Cabot Divs. of National Pneumatic Co., Inc., 125 Amory St., Boston 19, Mass.*

Circle No. 30 on reply card

SMALL DELAY relay is adjustable despite seal.

A new, hermetically sealed thermal time delay relay, less than 1⅜ in. long, provides lapses in five ranges from 5 to 99 sec. Each range can be adjusted from the outside of the case without disturbing hermetic sealing. Coils in stock range from 6.3 to 115 vac or vdc. Spst normally open or closed contacts carry 3 amps at 115 vac. *Bell-*

tron Mfg. Co., 204 Second St., Elizabeth, N. J.

Circle No. 31 on reply card

TIMER: Independent on-off ranges distinguish the Ferrara Model T 3. Its contacts are rated at 20 amps, 115 vac noninductive. Accuracy is said to be within 1 per cent for the standard ranges of 0.3 to 25 sec and 0.5 to 50 sec per section. *Ferrara, Inc., 8106 W. Nine Mile Rd., Oak Park 37, Mich.*

Circle No. 32 on reply card

POTENTIOMETERS

QUARTER-INCH trimmer pot sheds 1/4 watt.

Although little larger than the shaft of the average pot, a new pea-sized product packs a minimum of 100 turns of resistance wire and handles up to ¼ watt. Electrical travel is 320 deg, size 0.288 in. OD by 0.430 in. long. Resistances are available from 680 to 4,700 ohms. *Carter Mfg. Corp., Hudson, Mass.*

Circle No. 33 on reply card

MINIATURE POT has several favorable options.

Listed as model RVG-10 is a new miniature pot available with resistances ranging from 20 to 30,000 ohms and linearity within 0.25 per cent when specified. *The Gamewell Co., Newton Upper Falls 64, Mass.*

Circle No. 34 on reply card

ONE-INCH TEN-TURN POT: A redesigned ten-turn pot, 1 in. in diam and 1 in. long, is rated at 2 watts with linearity within ½ per cent, and resistances ranging from 500 to 100,000 ohms. *Circuit Instruments, Inc., P. O. Box 355, 1927 First Ave. South, St. Petersburg, Fla.*

Circle No. 35 on reply card

PRECISION 10-TURN: Featuring linearity within 0.015 per cent is a new 5-watt, 10-turn pot that runs with 0.60 oz-in. torque. Resistance range is from 2 to 100 K ohms, and size is 2 in. OD by 2 3/32 in. long. *Analogue Controls, Inc., 39 Roselle St., Mineola, N. Y.*

Circle No. 36 on reply card

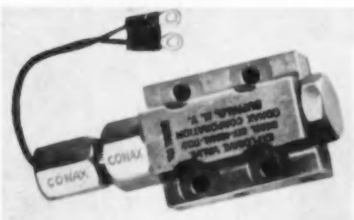
50-WATT POT: A new ring-type rheostat can be supplied with resistances up to 20,000 ohms. It is designed for industrial controls subject to severe mechanical shock. Size is 2 5/8 in. OD by 1 3/8 in. long. *Ward Leonard Electric Co., Mount Vernon, N. Y.*

Circle No. 37 on reply card

PRECISION POT: Among the features of a new pot, model 748-E, whose linearity is to within 0.1 per cent and even higher on special order, is its ability to accept up to 33 taps. Six can be ganged without disassembling any of them. The starting torque is 1 oz-in., OD-3 1/4 in., and resistance range 80 to 150,000 ohms. *Fairchild Camera and Instrument Corp., Hicksville, N. Y.*

Circle No. 38 on reply card

CONTROL VALVES



5,000-PSI valve explodes open in 0.002 sec.

Normally closed against pressures of up to 5,000 psi, this cigar-sized valve can be opened in 0.002 sec by a 1/2-amp current. Gases from the explosion that performs the feat do not enter the system or escape into the atmosphere. Operation of the one-shot device is completely silent. Flow passage in the valve is equivalent to 3/32 in. diameter. *Explosive Products Div. of Conax Corp., 7811 Sheridan Drive, Buffalo 21, N. Y.*

Circle No. 39 on reply card

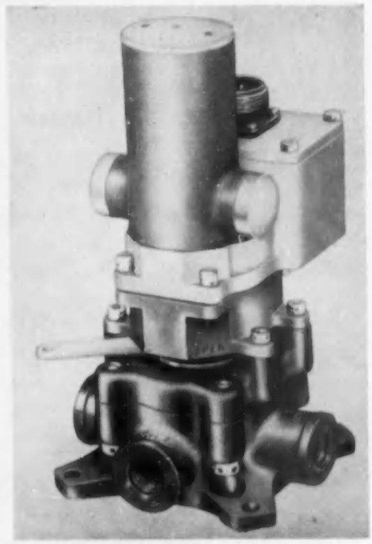
NEW PRODUCTS

3-POSITION SOLENOID VALVE: A new three-position double-solenoid four-way valve features a neutral position. In the open-center model, this position allows the controlled cylinder rod to move free. In the closed model, it locks the cylinder. *Mechanical Air Controls, Inc., 10030 Capital, Oak Park, Detroit 37, Mich.*

Circle No. 40 on reply card

DOUBLE-SOLENOID VALVE: A new double-solenoid pilot-operated four-way valve requires only momentary electrical contact. It will operate at up to 600 cpm. Solenoid coils for a variety of ac or dc voltages are available. *Valvair Corp., 454 Morgan Ave., Akron 11, Ohio.*

Circle No. 41 on reply card



SELECTOR VALVE'S speed eliminates oil shock.

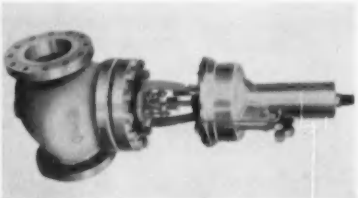
A new four-way selector valve is motor-driven to new positions in half a second, thus eliminating hydraulic shock. The valve remains in that position without power consumption. Operating pressures are to 3,000 psi. Both 3/8 and 1/2 in. sizes come with 24 vdc motors. *General Controls Co., Glendale, Calif.*

Circle No. 42 on reply card

PNEUMATIC GATE: A new gate-type valve for pneumatic materials handling systems cuts off inactive lines or isolates portions of a system. Avail-

able valve sizes range from 4 to 12 in. They have pneumatic operating cylinders. *Allen-Sherman-Hoff Co., 259 E. Lancaster Ave., Wynnewood, Pa.*

Circle No. 43 on reply card



BASIC control valve adapts to many variations.

Inverting the superstructure of this diaphram-operated control valve reverses the action with respect to control pressures. Sizes from $\frac{1}{2}$ to 8 in. will be available in the new S-3000 series. All internal parts are removable through the valve bonnet. *The Hammel-Dahl Co., 175 Post Road, Warwick Industrial Park, Providence 5, R. I.*

Circle No. 44 on reply card

POWER SOURCES

300-V POWER SUPPLY: Low noise-300-v power-and precise regulation are said to be the features of a new power supply. Model 2 will deliver up to 1 amp at 300 v. Input supply frequency can vary from 50 to 800 cps. but ripple stays under $\frac{1}{4}$ millivolt. *Eastgap Co., 285 Columbus Ave., Boston 16, Mass.*

Circle No. 45 on reply card

15-V POWER SUPPLY: A new power supply delivers up to 1 amp at from 0 to 15 v and offers extremely close regulation despite line voltage changes. Plug-in chopper-type stabilizing units, which are optional, hold output drift to within one millivolt in 24 hrs. Load variations up to one amp do not affect output more than 5 millivolts with the stabilizer at work. *Consolidated Electrodynamics Corp., 300 N. Sierra Madre Villa, Pasadent 15, Calif.*

Circle No. 46 on reply card

HV POWER SUPPLY: While the output of power supply model PS-22 is regulated within 0.01 per cent despite a load change from 0 to 1 ma, input changes of 10 per cent will

alter the 500-to-1,500 vdc output less than 0.05 per cent. A zero-drain thermally insulated battery provides voltage reference. *Scientific Specialties Corp., Snow & Union Sts., Boston 35, Mass.*

Circle No. 47 on reply card

BATTERY SUBSTITUTE: Model KM81 Aircraft Battery Substitute operates from 115 vac 60 cps single phase to provide a continuously variable 0 to 30 vdc output. Ripple is under 1 per cent at the maximum output of 10 amps. *Opad Electric Co., 69 Murray St., New York 7, N. Y.*

Circle No. 48 on reply card

POWER SUPPLY: Four new model KR series power supplies are offered to provide 1.5 amps through the 0 to 150, 100 to 200, or 195 to 235 volt range. Regulation is to within 0.2 volts for the full range of loads, and to within 0.2 volts for 105-to-125-volt line variations. Ripple is under 3 millivolts. Two unregulated 6.3 filament supplies deliver 15 amps at 6.3 volts. Height is 12¼, width 19, and depth 17 in. *Kepco Laboratories, 131-38 Sanford Ave., Flushing 55, N. Y.*

Circle No. 49 on reply card

SILICON POWER RECTIFIER: A new silicone power rectifier operates at temperatures up to 150 deg C, and boasts efficiencies up to 90 per cent and 14 amp half wave ratings. Peak inverse voltage; 100. *Bogue Electric Mfg. Co., 52 Iowa Ave., Paterson, N. J.*

Circle No. 50 on reply card

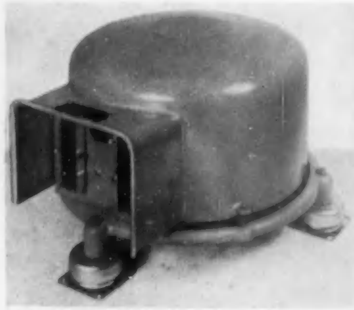
VOLTAGE REGULATOR: Model MA1000S is said to hold voltages to within ½ per cent against line or load variations. It uses a magnetic amplifier controller with a silicone diode reference element. Output range is 0 to 1,000 va. *Sorenson & Co., 375 Fairfield Ave., Stamford, Conn.*

Circle No. 51 on reply card

HIGH TEMP TRANSISTORS: Said to withstand high temperatures are two new transistors for audio or low rf applications. They have power dissipation ratings for 50 milliwatts at 135 deg C. Maximum reverse emitter voltage is 22. *Raytheon Mfg. Co., 55 Chapel St., Newton 58, Mass.*

Circle No. 52 on reply card

DIGITAL DEVICES



MAGNETIC DRUM stores 42,000 bits at 3,550 rpm.

Model ERA 1114 Drum contains its own motor, and uses 20 information tracks. This model is the sixth of the standard Univac line. *Remington Rand Univac Div. of Sperry Rand Corp.*, 1902 W. *Minnehaha Ave., St. Paul 4, Minn.*

Circle No. 53 on reply card

PHOTO-ELECTRIC converter contains own preamps.

The principle behind the design of this analog-to-digital converter is just about the same as the one behind the Baldwin Piano converter described last month. A transparent code disc gets in the way of a flashing light, with photo-cells doing the sensing. The converter also contains its own potted transistorized preamplifiers to yield an output of 3 volts across 3,000 ohms. By flashing the light source, readouts at up to 100 per sec without ambiguity result. Thirteen channels are coded by the fist-size machine, converting shaft position into 8,192 parts. A power supply, operating from 115 v 60 cps

INDIANA
PERMANENT MAGNET
DESIGN INFORMATION

published for industrial and consumer product engineers and designers

HOW PERMANENT IS A PERMANENT MAGNET?

Permanent magnets *are* permanent. Proof of permanence is substantiated by many practical applications over long periods of years.

The continued accuracy of some of the most exacting scientific electrical measuring instruments, or of the familiar house-type, watt-hour meter depends upon a permanent magnet.

The speedometer in your car, the magneto in your power lawn mower, or your wife's magnetic knife rack in the kitchen may be consigned to the junk pile in time because of mechanical failure or obsolescence . . but definitely not because of magnetic failure.

There is a common belief . . which is incorrect . . that a permanent magnet supports its external magnetic field by dissipating some of its *internal* magnetic energy. This definitely is not the case.

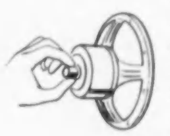
Adverse Factors on Remanent Magnetism. The magnetism of a permanent magnet can be adversely affected by any one, or a combination of, the following:

Elevated Temperatures can cause very appreciable initial losses in magnetism, up to complete demagnetization, even though metallurgical properties are not affected.

External Magnetic Fields from electro-coils, high electrical currents, or even other permanent magnets can partially or completely demagnetize the permanent magnet, and obviously, if the field is sufficiently strong, completely reverse the polarity.

Contact with Ferromagnetic Material by a permanent magnet in such a way that the normal internal field pattern is distorted can adversely affect the remanent magnetism. This is an important condition to avoid in the handling of magnetized magnets.

Changes in the Magnetic Circuit such as to produce a larger air gap than that on which it was initially magnetized, will reduce the strength of the magnet instantly and it is not recovered by reassembly to the original gap. A typical radio loud-speaker magnet, if removed from its associated steel circuit, then reassembled without remagnetizing, may lose as much as two thirds of its initial strength.



Vibration and Shock have little effect in most applications.

In all of these cases where only the remanent magnetism has been affected, losses can be recovered by remagnetization.

This article is a condensed version of a recently published feature article carrying the same title. Reprints of the full length article are available on request.

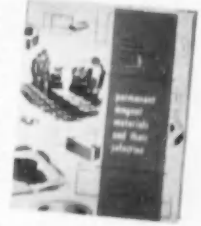
For assistance in designing the most efficient magnet for your product, consult our design engineers—without obligation, of course.

Magnetic Materials Exhibit at IRE Radio Engineering Show

Members of the magnetic materials design and application engineering staff of Indiana Steel Products Company will man the company's exhibit at the forthcoming IRE Radio Engineering Show in New York, Monday, March 19 through Thursday, March 22.

The exhibit, located in Booths 2 and 4 at Kingsbridge Palace, will feature a full line of permanent magnets including Cast Alnico . . Sintered Alnico . . Indox Ceramic Magnets . . and Cunife.

New manual discusses selection of permanent magnet materials



This newly published, 12-page manual entitled, "Permanent Magnet Materials and Their Selection," discusses physical and magnetic characteristics and the applications of Cast Alnico Magnets (Grades I, II, III, IV, V, VI, XII); Sintered Magnets (Alnico II, IV, V, VI, Indalloy and Indox I); Ductile Magnets (Cunico and Cunife I) and Formed Magnets (Chromium and Cobalt).

Also included is a selector-type chart which lists magnetic characteristics, design factors, material characteristics, and manufacturing methods and limitations of the various magnetic materials. In addition, special sections present a "Glossary of Magnetic Terms" and a list of magnetic "Symbols."

Copies of this publication are available on request. Ask for Manual 5-P-3 on your company letterhead.

THE INDIANA STEEL PRODUCTS COMPANY
Valparaiso, Indiana
WORLD'S LARGEST MANUFACTURER OF PERMANENT MAGNETS

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MAGNETS

current, is also available. *Electronics Corp. of America, Cambridge, Mass.*

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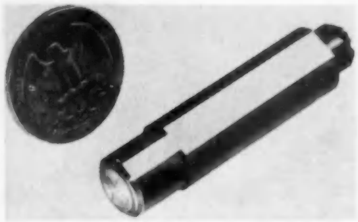


MAGNETIC DRUM heads now in production.

Now in production are magnetic drum heads that generate up to 1.5 volts peak to peak on readback. A 40-ma writing current will completely saturate a 0.001-in. coating of red oxide on a drum 0.002 to 0.004 in. away. The flat on the side of the head is milled while electronically locating the position of the slit in order to insure perfect verticality between the two. *J. B. Rea Co., 723 Cloverfield Blvd., Santa Monica, Calif.*

Circle No. 55 on reply card

PULSE TRANSFORMERS: A new M series pulse transformer weighs only 4 grams, measures 0.44 in. in diam and can be wound to cover a range of pulse widths from 0.05 microsec to 2.0 microsec. *Technitrol Engineering Co., 2751 N. Fourth St., Philadelphia 33, Pa.*

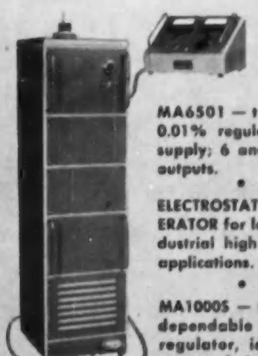
Circle No. 56 on reply card

CONTROL COMPONENTS

PNEUMATIC CHART DRIVE: Pneumatic pulses can originate as far as 250 ft from the chart they drive. The drive mechanism is offered for installation where other types of chart drives are undesirable. A cam-operated pneumatic flapper valve is the pulse generator. The assembly can power up to 57 recorders as far as 100 ft away, or 25 instruments 250 ft away. *Industrial Div. of Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.*

Circle No. 57 on reply card

MA6501



MA6501 — tubeless 0.01% regulated DC supply; 6 and 2 volt outputs.

•

ELECTROSTATIC GENERATOR for lab or industrial high-voltage applications.

•

MA1000S — tubeless, dependable 1000VA regulator, ideal for unattended installations.

MA1000S

NEW PRODUCTS . . . BROADER ENGINEERING HORIZONS FROM SORENSEN

MR3215 5-32VDC AT 0-15 AMPS
new, tubeless, magnetic amplifier

WIDE RANGE REGULATED DC POWER SUPPLY

for versatile, trouble-free performance in countless design & test applications

Different outside . . . and *inside!* The latest design in magnetic amplifier regulation. A silicon diode is used as reference element and a transistor amplifier provides the control current for the magnetic amplifier. Wide range, continuously adjustable voltage at high current. Regulation ±0.5% against line or load, ripple 1% RMS. Versatile, dependable, rugged, economical.

VISIT BOOTH 646 CIRCUITS AVENUE, I.R.E. SHOW

◄ *Also see these other new products plus computer power supplies and Sorensen's developments in industrial ultrasonics.*

Sorensen

SORENSEN & COMPANY, 375 FAIRFIELD AVENUE, STAMFORD, CONN.

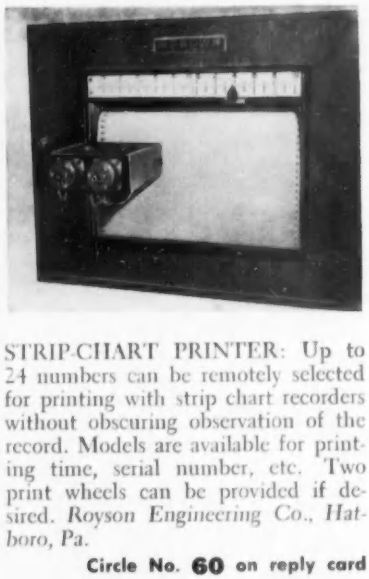
NEW PRODUCTS

RESISTANCE STANDARD: Twelve 100-kilohm resistors accurate to within 0.0015 per cent can act as a basic comparison standard for resistances ranging from 8.25 kilohms to 1.2 megohms. The resistors in the standard are stable to within 5 ppm per deg C. *Julie Research Laboratories Inc., 341 East 149th St., New York 51, N. Y.*

Circle No. 58 on reply card

LOW-VOLTAGE CAPACITORS: A new line of ceramic-type capacitors, intended for low-voltage transistor circuits, ranges from ⅛ to ½ in. sq. They're rated for 75 v max and offer capacitances of from 0.001 to 0.1 mfd. *Gulton Industries, Inc., Metuchen, N. J.*

Circle No. 59 on reply card



STRIP-CHART PRINTER: Up to 24 numbers can be remotely selected for printing with strip chart recorders without obscuring observation of the record. Models are available for printing time, serial number, etc. Two print wheels can be provided if desired. *Royson Engineering Co., Hatboro, Pa.*

Circle No. 60 on reply card

NEW CONNECTORS: A new principle in a line of miniature cable connectors results in a simple pushing together to connect, but a twist as well as pull to disconnect. *Nugent Electronics Co., Inc., 621 E. 8th St., New Albany, Ind.*

Circle No. 61 on reply card

TUBING CONNECTOR: A shutoff valve incorporated in the Swagelok Quick Connect Fitting prevents any leakage during the connecting or disconnecting operation. *Crawford Fitting Co., 884 E. 140th St., Cleveland 10, Ohio.*

Circle No. 62 on reply card

For More Information

from ADVERTISERS

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(100) UNIFORM SPRING. Hunter Spring Co. Bulletin, 16 pp. Covers characteristics, properties, materials, types of ends, mountings, and design formulas and standards of what is said to be the only compression spring to exert the same force at any deflection.

(101) FINE PITCH GEARS. PIC Design Corp. Catalog 8. Describes nylon, phenolic, and helical units offered from stock for the first time. Also covers fine pitch racks, miter gear boxes, pulleys, and vernier and dial sets.

(102) GEAR TRAIN DESIGN. Washington Machine & Tool Works, Inc. Pamphlet. "Gear Train Design Simplified" suggests economical approach to precise miniaturized gear trains. Considers low torque, essentially zero backlash.

(103) OIL-FREE AIR PUMP. Lear-Romec Div. of Lear, Inc. Data Sheet 2-21. Explains how carbon-graphite, self-lubricating sleeves in both cylinders of a two-stage pump obviate oil and adequately seal against leakage. Pump rated at 1,000 hrs continuous at temperatures as low as minus 65 F ambient.

(104) RESISTANCE DECADE. Consolidated Resistance Co. of America, Inc. Data sheet 128. Device described has been modified since first noted (November, page 125) to carry an infinite resolution slide wire rheostat for vernier adjustment to within 0.002 ohms and pushbuttons for connecting and shorting out.

(105) HYDRAULIC TEST STAND. Auto-Control Laboratories. Data sheet C-55-2 and Component Chart List 7-55-2. Sheet tells how variable pressures of from 500 to 5,000 psi are put to work in testing the many components in the chart.

(106) PHOTOELECTRIC CELL. Special Products Div. of Eastman Kodak Co. Booklet, 24 pp. Says a small, rugged, lead sulphite Ektron detector is highly sensitive to heat radiation, has no mechanical microphonics, is easily grouped.

(107) VIBRATION NOTEBOOK. MB Mfg. Co. Vol 1, No. 3, 8 pp. Chief Engineer Karl Unholtz's lead article tells why it is important to eliminate as much spurious table motion as possible. Donald Vannorsdall scores a point for pressure-sensitive tape.

(108) AIR CYLINDERS. Petch Mfg. Co. Catalog, 12 pp. Gives air pressure, force, and volume data for bores of from 1 in. to 8 in. The five cylinders covered, all designed for 200 psig, have interchangeable mountings.

(109) MINIATURE CONNECTORS. DeJUR Amsco Corp. Bulletin, 4 pp. The company has miniaturized its AN-type connector, and the bulletin describes results. Rating is 7.5 amps. Interchangeable inserts are permanently swaged into shell.

(110) ELECTRONIC EQUIPMENT. Davenport Mfg. Co. Form 55G-U, 20 pp. This is Davenport's first catalog. Data in it cover ac and dc voltage units, megohm test units, laboratory standard meters, voltmeters, shunts, current transformers, and phase sequence indicators.

(111) MOSTLY AIRBORNE. Electronics Div. of Huffard Machine Works, Inc. Circular, 4 pp. Deals with autopilot amplifiers and components, airborne power supplies, transistorized static inverter, voltage regulator.

(112) SOLENOID VALVES. J. D. Gould Co. Bulletin K, 4 pp. Presents new additions to the line. Among them: NC and NO types, 1¼, 1½, and 2 in. in size, designed to eliminate hammer and shock in control of liquids. Maximum pressure is 1,000 psi (oil and water).

(113) MINIATURE POTENTIOME-

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TERS. Waters Mfg. Co. Aerohm data sheet. Treats miniature low-torque, micro-miniature, and miniature precision wire-wound potentiometers with resistance ranges of from 10 to 100,000 ohms.

(114) MEASUREMENT INSTRUMENTS. Waters Mfg. Co. Catalog. Specs for, and applications of, a wide-range inductance bridge, filter chokes, transformers, plate reactors, a cathode interface impedance bridge, a crystal diode curve tracer, and a torque-watch gage.

(115) GERMANIUM RECTIFIERS. Hanson-Van Winckle-Munning Co. Bulletin GR-100, 4 pp. About new units with voltage regulation of plus or minus 5 per cent and a low voltage drop. They have low forward resistance of the junction, high reverse resistance.

(116) NEWS FROM BECKMAN. Beckman Div. of Beckman Instruments, Inc. "The Beckman Bulletin", No. 17, 8 pp. Lead article tells about a simplified mass spectrometer that becomes a leak detector when a helium-ion beam is passed through radio-frequency gaps. Only the resonant ions make the grade.

(117) B-L EQUIPMENT. Benson-Lehner Corp. Brochure, 4 pp. Benson-Lehner wheels out its complete line of data-reduction equipment and components in this two-color folder. Included are analyzers and recorders, plotters, projectors, recti-linear potentiometers, and the Key-pak digital keyboard.

(118) BIMETALLIC THERMOMETER. Taylor Instrument Cos. Bulletin 98267, 4 pp. All about a Therm Dial Thermometer, which operates on the two-coefficients-of-expansion principle. It's accurate to plus or minus 1 per cent of range, is unaffected by ambient temperatures. Stem lengths: 4, 6, 9, 12 in.

(119) PIPING ANALYSIS. Fabricated Products Div. of the M. W. Kellogg Co. Booklet, 12 pp. Discusses Kellogg's "general analytical method of piping flexibility analysis", which puts simultaneous equations to work on a system's forces and moments. Also describes piping model test.

(120) TIME-FILL DIAGRAMS. Hays Mfg. Co. Folder 209, 2 pp. One chart shows time in minutes for filling in pints and quarts, the other deals with seconds, ounces, and pints. Both charts suitable for pressures up to 150 psi.

(121) ELECTRONIC COMPONENTS. Mandex Mfg. Co., Inc. Catalog, 60 pp. Tube sockets, terminal strips, lugs, plugs, etc., share the spotlight in Mandex's first major rundown.

(122) SCALER-TO-COUNTER. Nuclear Measurements Corp. Catalog, 4 pp. Describes what NMC calls the first completely self-powered proportional counter converter. Instrumental error is less than 1 per cent.

(123) SAMA TALKS. Scientific Apparatus Makers Association. Booklet, 6¼ by 8¼, 16 pp. SAMA's idea in telling about itself in "You . . . and the Instrument Industry" is to encourage more engineers to take an active part in its affairs. Not a bad idea at all.

(124) TWO FROM HOLLAND, N. V. Hollandse Signalapparaten. Two gate-fold bulletins, 6 pp. each. Deal with two related instruments for checking and measuring servo performance.

(125) CONTROLLER PARTS. Brownell Distributors, Inc. Catalog 55, 116 pp. including price list. Lists renewal parts available from 17 manufacturers. It's said to be the first complete compilation of its kind. A valuable reference.

(126) QUICK-DISCONNECT. The Deutsch Co. Bulletin, one sheet. Describes miniature connectors that operate within a minus 67 to plus 250 deg F range. They provide for visual inspection of assembly and installation.

(127) ELECTRONIC TIMERS. G. C. Wilson & Co. Brochure, 6 pp. Covers delay, repeat cycle, and interval timers.

(128) TACHOMETERS. Metron Instrument Co. Bulletin 105, 4 pp. Treats a line of stationary units whose indicators can display information from take-off heads mounted on two to ten pieces of equipment.

(129) LIMIT SWITCH. E. W. Bliss Co. Bulletin 33, 4 pp. Among the features of a mechanical rotary machine tool unit covered here: independent 360 deg adjustment, presetting to within 1 deg, operation at either NO or NC.

(130) SPECTROPHOTOMETER. Applied Physics Corp. Bulletin RB2-57-5C, 6 pp. Describes (with performance photographs) the Cary Model 81 Raman Instrument, attributing to it high light gathering power, freedom from effects of scattered light, and high zero stability.

(131) TUBE REPLACEMENT GUIDE. General Electric Co. Booklet ETI-719B, 8 pp. In this new edition, GE lists 282 types of power tubes for which it has a direct replacement.

(132) THERMOSTAT METALS. American Silver Co. Card, 3½ by 6. This equivalence chart compares the properties of thermostat metals produced by four manufacturers, including Silver.

(133) PRECISION POTENTIOMETERS. Fairchild Controls Corp. Bulletin, 6 pp. Project Engineer Aaron Blaustein examines the potentiometer part of the "pot" and discusses the techniques and materials that make it "precise".

(134) FILMPOTS. Fairchild Controls Corp. Bulletin, 4 pp. Project Engineer Lawrence Krause shows how the concept of a metal film as a resistance element grew, illustrates advantages. Good views of Fairchild's Model 771.

(135) HEAVY-DUTY VALVE. Magna-

trol Valve Corp. Bulletin 89. Describes a packless solenoid valve for soluble oil, hydraulic oil, or water, at fluid temperatures to 212 deg. F. Can be fitted with a dashpot for independent regulation of opening and closing speeds.

(136) THERMOCOUPLE INSULATORS. Stupakoff Div. of the Carborundum Co. Catalog Section 356, 6-pg. gatefold. Lists sizes and shapes of available tubes and properties of magnesia and aluminum silicate, the two materials used.

(137) STABILIZING AMPLIFIER. George A. Philbrick Researches, Inc. Bulletin K2-P. About a new, plug-in type, electronic analog component with gain of 1,000 and input-offset and long-term drift of less than 1 millivolt.

(138) HYDRAULIC POWER. Char-Lynn Co. Form SD B 05, 16 pp. Describes hydraulic pumps, supply tanks, valves, hose couplers, filters, and cylinders. Fundamentals of hydraulics shown graphically.

(139) SERVO AMPLIFIERS. Servo Corp. of America. Bulletin TDS-1120-4, 4 pp. Covers four new units: a 60-cycle two-phase motor control, a 400-cycle reluctance amplifier that accepts two ac and one dc input, and two plug-in units.

(140) THERMOCOUPLE WIRES. Revere Corp. of America. Engineering Bulletin 1701, 12 pp. Not just wires, but extension leads, too, are treated from these points: insulations, saturants, and metallic braids, military part numbers, and specifications.

(141) RATEMETER. Research & Control Instruments Div. of North American Philips Co., Inc. Folder, 4 pp. Covers operation and applications of a six-digit scaler for proportional, scintillation, or Geiger counting.

(142) X-RAY UNIT. Research & Control Instruments Div. of North American Philips Co., Inc. Deals with a Norelco improvement that provides 40- or 120-deg apertures for rapid inspection of welds, pipe lines, power plants, and ship and aircraft equipment.

(143) ENVIRONMENTAL TESTING. General Testing Laboratories, Inc. Brochure, 9 pp. A brief tour of the facilities of this Carlstadt, N. J., company.

(144) VIBRATION DATA. The MB Mfg. Co. "The Vibration Notebook", 8 pp. We're finally catching up with this new periodical on vibration testing, measurements, and isolation.

(145) GAGING MACHINES. Pratt & Whitney Div. of Niles-Bement-Pond Co. Circular 592, 12 pp. Describes P&W's Sigmatic machines, which check many dimensions simultaneously with assembled standard units. Indicator retains reading until the next part is inserted.

(146) JUNCTION TRANSISTORS. Communications & Electronics Div. of Motorola, Inc. Bulletin ATIC-967, 8 pp. The authors, members of the Transistor Research Dept. of the Motorola Research Laboratory, present a treatise on junction transistors.

(147) AUTOMATIC MACHINING. Snyder Tool & Engineering Co. Booklet, 24 pp. Illustrates single- and multi-station machines for transferring, profiling, drilling, counterboring, facing, finishing, etc., and defines automation words and phrases.

BIMETAL FOR THERMOSTATS: Said to be the most economical thermostat metal in its range, ASC-3 can be had in spirals, helical coils, flat blades, cantilever strips, or other shapes, in thicknesses down to 0.001 in. and widths down to 0.093 in. It produces linear deflections in the range of minus 100 deg and plus 800 deg F. Maximum sensitivity is in the range of 200 to 600 deg F. *American Silver Co., 36-07 Prince St., Flushing 54, N. Y.*

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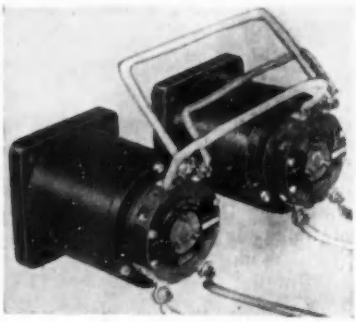


RUGGED synchros designed for 115 v, 60 cps power.

Pull-out torque of 1.7 oz-in. minimum over a speed range of 0 to 1,600 rpm at 25 deg C combines with an electrical accuracy of within 1 deg in new, rugged little synchros. They are intended for use in pairs as drivers and receivers. Weight of the size 23 unit is under 1½ lb. *Avionic Div. of John Oster Mfg. Co., 1 Main St., Racine, Wis.*

Circle No. 64 on reply card

DECADE INDUCTOR: A range from 0.001 to 11.11 henries in 0.001-henry steps to an accuracy of within 1 per cent is the function of Model 1210 decade inductor. *Stasta Div. of Beckman Instruments, Inc., P. O. Box 296, Station A, Richmond, Calif.*

Circle No. 65 on reply card

CONTROLLED WARM-UP TUBE: A new medium mu twin-triode miniature equivalent of the 6SN7-GTB has a controlled heater warm-up characteristic of 11 sec. Maximum plate voltage is 300, transconductance 2,600 micromhos. *General Electric Co., Schenectady 5, N. Y.*

Circle No. 66 on reply card

NEW PRODUCTS

LOCKING CONNECTORS: The polarizing pins of Continental E-Z release are threaded to enable positive vibration-proof locking and separation without forcing or prying. *Dejur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N. Y.*

Circle No. 67 on reply card

DELAY LINES: A new series of delay lines, only 0.4 in. in diam., can be fuse-clip mounted. Three general designs offer low, medium, or fast rise time coupled with the converse delay per cubic inch. Most of the units are carried in stock, says the maker. *PCA Electronics, Inc., 2180 Colorado Ave., Santa Monica, Calif.*

Circle No. 68 on reply card

HEATING ELEMENT: A new stainless-steel rod-like heating element with maximum surface temperatures of up to 1,250 deg F is offered for controlling the ambient temperature of indicating and control apparatus. Standard units consume from 40 to 1,500 watts. *Hotwatt, Inc., 16 Gould St., Danvers, Mass.*

Circle No. 69 on reply card

PRECISION CODE DISCS: A unique optical technique, recently developed, enables the production of code discs with graduations as narrow as 3 microns. Circles from 1 to 12 in. in diam can be divided into as many as 2,000 lines per peripheral inch. Because the process uses exposure of only 1/89000 sec, it requires a number of repeat exposures to make any effect on the emulsion. This yields an averaging effect, which is largely responsible for the method's accuracy. *Precision Photomechanical Corp., 170 S. Van Brunt St., Englewood, N. J.*

Circle No. 70 on reply card

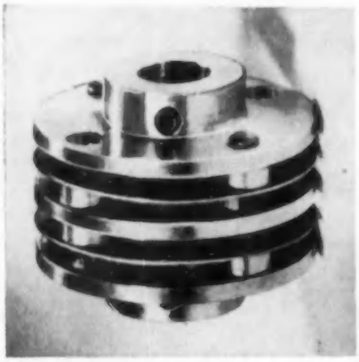
CONDUCTIVITYCONTROLLER: Type RI Indicator-Controller, used for the measurement and control of solution conductivity, now has a pneumatic output. Switch action is also available for electrical control. *Industrial Instruments, Inc., Cedar Grove, N. J.*

Circle No. 71 on reply card

MINIATURE VOLTAGE DIVIDER: Encapsulated in a housing enabling the dissipation of ½ watt at room temperature, a new voltage divider has three resistance elements and four

terminals. It's only $\frac{1}{4}$ in. in diam and has up to 100 K ohms per section, accurate to within 0.5 per cent. *The Daven Co., Livingston, N. J.*

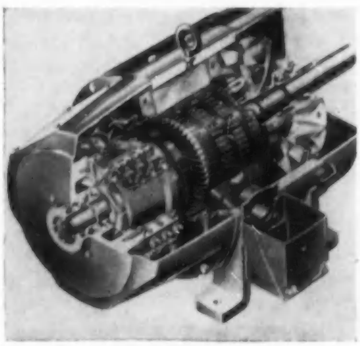
Circle No. 72 on reply card



FLEXIBLE coupling rules out backlash.

Flexible coupling C 300 can be used with shafts between $\frac{1}{8}$ and $\frac{5}{16}$ in., with angular misalignment of up to 6 deg. The coupling consists of three discs setscrew-fixed to its shafts. *Oerlikon Tool & Arms Corp. of America, P. O. Box 3049, Asheville, N. C.*

Circle No. 73 on reply card



NEW FEATURES up temp limit, ease maintenance.

New insulation (at A and B above) emphasizing inorganic materials and ruggedized easy-to-get-at brush holders (C,) are among additions to GE's motor line aimed at increasing heat resistance and ease of maintenance. Other variations include a lightweight aluminum fan and improved ventilation system. *General Electric Co., Schenectady 5, N. Y.*

Circle No. 74 on reply card

POTTING COMPOUND: A new epoxy compound, HYSOL 6600, has been developed especially for potting large metal masses such as transformers. When processed with its hardener, the otherwise low-tempera-

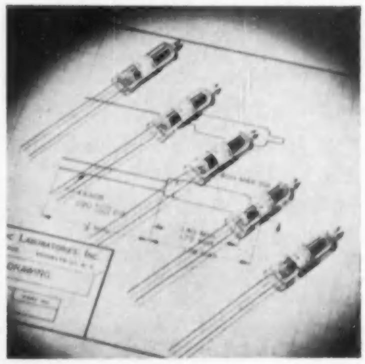
ture melting material becomes hard and heat resistant. *Electrical Insulating Materials Div., Houghton Laboratories Inc., 322 Houghton Ave., Olean, N. Y.*

Circle No. 75 on reply card

GEARED JOINT transmits torques around 315 deg.

In addition to taking on speeds of up to 500 rpm, a new group of geared joints features needle bearings said to improve efficiency over 60 per cent above previous models, while lowering costs at the same time. Three models offer torques of 500 to 3,500 lb-in. *Stow Mfg. Co., Binghamton, N. Y.*

Circle No. 76 on reply card



CORONA effect controls 30 kv in miniature regulators.

A new line of miniature and subminiature fixed and adjustable corona discharge voltage regulator tubes is suitable for stabilizing voltages from 300 to 30,000 volts at currents below several ma. Voltage regulation can be kept within 1 per cent. A "Vari-

just" design utilizes a metal bellows and drive mechanism to vary the gas pressure in some models for smoothly adjustable regulated voltages. *Anton Electronics Laboratories, Inc., 1226-38, Flushing Ave., Brooklyn 37, N. Y.*

Circle No. 77 on reply card

SCREW-LOCKED CONNECTORS: The ease of jackscrew connection has been added to the popular Winchester MRE line. The screws have knurled heads. *Winchester Electronics, Inc., Dept. W, Norwalk, Conn.*

Circle No. 78 on reply card

MINIATURE CABLES: A new line of miniature high temperature shielded and jacketed cables contains as many as 24 conductors. Made to MIL specs, each conductor can be had with various striped color coding. The jackets are made of Teflon, Kel-F, or a glass fibre braid. *Hitemp Wires, Inc., Mineola, N. Y.*

Circle No. 79 on reply card

PRINTED-CIRCUIT DELAY LINES: A new series of custom-built delay lines has leads extending at any angle, and is intended for low-cost printed-circuit application. *ESC Corp., 534 Bergen Blvd., Palisades Park, N. J.*

Circle No. 80 on reply card

ABSTRACTS

Diagrams Transformed

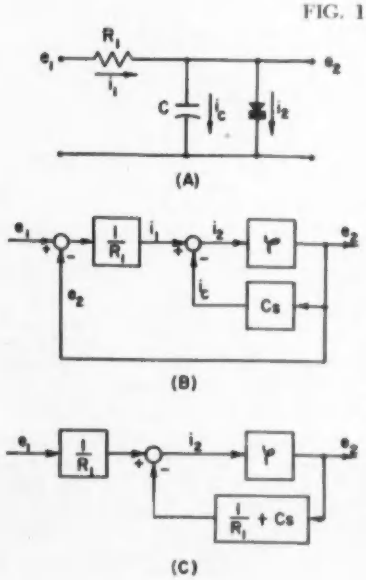
From "Block Diagram Transformations for Systems with One Nonlinear Element" by T. M. Stout, Schlumberger Instrument Co. Paper 56-196, AIEE Committee on Feedback Control Systems, presented at the AIEE Winter General Meeting, Jan 30 to Feb. 3, 1956.

Dr. Stout reviews eight of Graybeal's rules for the transformation of block diagrams, adds one new rule, and then examines their validity for nonlinear systems. The results lead to a wider application of block diagrams, already widely used in the study of complex dynamic systems.

Rather than require algebraic manipulations of system equations "the block diagram approach has the advantage of maintaining close contact with the physical system, providing new insights into system operation, and suggesting formulations of nonlinear problems which may facilitate further analysis. The last point is particularly important since some of the difficulties in analyzing nonlinear systems may result from a poor choice of variables or from use, by force of habit, of an inconvenient description of the nonlinearity."

One section of the paper deals with block diagrams for electrical networks. A detailed analysis shows that any general electrical network containing a single nonlinearity can be represented by four topologically identical block diagrams. As pointed out,

FIG. 1



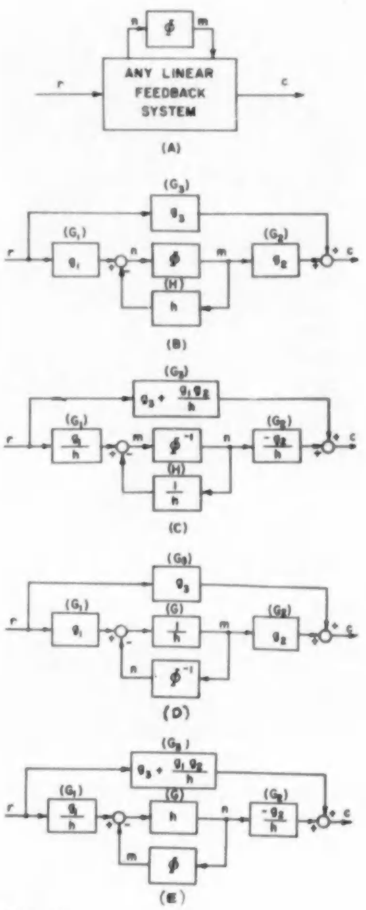


FIG. 2

"which block diagram provides the simplest and neatest representation of a particular network depends on the nature of the network."

This section of the paper also contains several examples of block diagram transformations of actual nonlinear circuits. One of these, shown in Figure 1, deals with a one-section R-C ladder network with a diode rectifier. Two transformations are shown in Figures 1B and 1C. These block diagrams are based on the rules given in the paper. Two other transformations (not shown) can be obtained by Dr. Stout's additional rule, such that the nonlinearity now appears in the "feedback" block. Other examples of block diagram conversion include a two-section R-C ladder network with diode, transformer with a nonlinear core material, and a bridged-T network with rectifier.

In the last section of the paper Dr. Stout analyzes a general feedback system with a single input, a single output, and one nonlinear element. This system is shown in Figure 2A, with the four topologically equivalent block transformations shown in the preced-

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ing illustrations. These block diagrams show "that the nonlinear element can be represented in either a forward path (B and C) or feedback path (D and E), with its input and output in their normal or original sense (B and E) or reversed (C and D). The neatest and simplest final diagrams seem to result when transmission through the nonlinear element is in the same direction in both the original and final diagrams." Which of these four forms to use depends on the nature of the original diagram.

Some shortcut procedures are included for finding the final diagram directly. These procedures are similar to the direct determination of voltage ratios and transfer immittances in electrical network problems. The procedures, quoted from the paper, apply to feedback control systems as generalized in Figure 2:

1) If the nonlinear element is a forward element, with input n and output m, the transfer functions of B can be evaluated from

$$\left.\frac{n}{m'}\right|_{r=0} = -h = -H$$

$$\left.\frac{n}{r}\right|_{m'=0} = g_1 = G_1$$

$$\left.\frac{c}{m'}\right|_{r=0} = g_2 = G_2$$

$$\left.\frac{c}{r}\right|_{m'=0} = g_3 = G_3$$

2) If the nonlinear element is a feedback element, with an input n and an output m, the linear transfer functions of E can be evaluated from

$$\left.\frac{n}{m'}\right|_{r=0} = -h = -G$$

$$\left.\frac{n}{r}\right|_{m'=0} = g_1 = G_1G$$

$$\left.\frac{c}{n}\right|_{r=0} = \frac{-g_2}{h} = G_2$$

$$\left.\frac{c}{r}\right|_{n=0} = g_3 + \frac{g_1g_2}{h} = G_3$$

In carrying out these calculations we imagine that the input and the output paths of the nonlinear block are opened and that a signal m' is supplied to the system in place of m.

Again Dr. Stout applies his general theory to specific examples. Among these are a positioning servomechanism with a nonlinear torque-current relationship, a positioning servo with nonlinear friction torque, and a conditional feedback arrangement.

Incidentally, the paper covers an interesting graphical technique for finding the equivalent operator for two nonlinear operators, as occurs in feedback systems. If $y = A_1(x)$, $v = A_2(y)$, and $u = x + v$, then u as a function of y can be found by a simple graphical process.

In conclusion, "The usual black diagram transformation rules can be applied to systems containing nonlinear elements, provided that certain restrictions are observed. Nonlinear blocks cannot be moved past summing points; the order of linear and nonlinear blocks cannot be reversed; and feedback loops cannot be reduced to equivalent blocks (except in special cases). Variables can be combined by addition and subtraction in any required order, and linear blocks obey the same rules as before, so that considerable modification and reduction of the block diagram is still possible."

Equations, Passive Analogs

From "Prediction of the Dynamics of a Concentric-Pipe Heat Exchanger", by J. M. Mozley, E. I. du Pont de Nemours & Co., Inc., ASC Christmas Symposium, 1955.

Once again the analytical approach to control systems is given a boost. Here the hardware is a simple heat exchanger. The author points out that in simple and economical systems, the flexibility built into the standard off-the-shelf controller may allow adjustments that will enable the show to go on without a hitch, but, for high-speed, low-capacity, high-cost systems, a little figuring may point to the need for some special gear. A "little figuring" has its limitations, he emphasizes, especially where high accuracy is needed and linear equations are used. Hence, half of the paper talks about passive network electrical analogs and their utility in dealing with heat exchanger problems. As with the Taylor paper given at the same session of the ASC, calculated and analogued results are checked with the real thing. Many phase-shift frequency-response curves are given.

Rather than utilizing the four simultaneous differential equations that commonly represent the operation of a heat exchanger, the author presents two simple linear equations that he says will do the trick this side of 180 deg phase shift. These are:

$$\left(\frac{M_1}{W_1}\right)\frac{dT_1}{dt} + T_1 + \frac{UA}{W_1c_1}(T_1 - T_2) = T_{1i}$$

$$\left(\frac{M_2}{W_2}\right)\frac{DT_2}{dt} + T_2 + \frac{UA}{W_1c_2}(T_2 - T_1) = T_{2i}$$

where

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A = heat transfer area, sq ft
M_1 = holdup of fluid in inner tube, lb
M_2 = holdup of fluid in annulus, lb
T_1 = temperature of fluid in inner tube, C
T_2 = temperature of fluid in annulus, C
C_1 = heat capacity of fluid in inner tube, Pcu/lb deg C
C_2 = heat capacity of fluid in annulus, Pcu/lb deg C
U = overall heat transfer coefficient, Pcu/min
W_1 = flow rate in inner tube, lb/min
W_2 = flow rate in annulus, lb/min

But because of the limit of this approach to a 180 deg phase shift, discretion must be used. The above model is pretty far off base when it comes to countercurrent operation. These equations can be solved for T_2 for sinusoidal variations in T_{1i} with $T_{2i} = 0$. The resulting expression is for the transfer functions of the heat exchanger, relating dynamic variations of exit cold fluid temperature and inlet hot fluid temperature.

$$\frac{T_2}{T_{1i}}(j\omega) = \frac{w_1c_1\,UA}{[M_1c_1\,(j\omega) + w_1c_1 + UA]} \times \frac{1}{\left[M_2c_2\,(j\omega) + w_2c_2 + \frac{UA}{2} - \left(\frac{UA}{2}\right)^2\right]}$$

This simplification lumps the distributed properties of the heat exchanger into one point in the longitudinal (x) direction, by assuming constant heat transfer coefficient and heat capacity, and by neglecting heat storage by the walls. It also assumes that the fluid on either side of the walls is well mixed. This means that the exit fluid temperature is equal to the bulk fluid temperature.

While the author says that the number of variables associated with heat exchanging are too great to expect the heat-exchanger maker to provide data on the dynamic behavior of his product, he wonders about the accuracy of a variety of predictions for various conditions. It would seem that there is room for exchanger makers to make statements on this score.

Rocket Control

From "Development of a Stabilizing System for the Viking Rocket", by N. E. Felt, Jr., The Glenn L. Martin Co., American Rocket Society paper 171-54.

Three subsystems guide the Viking rocket upward. First, there is the motor control system, which actually alters the line of thrust of the rocket motor. Next is the roll stabilization system, which operates aerodynamically through control tabs on two of

the rocket's fins. The third system uses small jet motors, and is applied when the main motor is inoperative.

As originally planned, the Viking was to reach an altitude of 100 miles carrying 500 lb of instruments. The propulsion system, like that of the V-2, uses a steam-driven pump to deliver alcohol and liquid oxygen to the thrust cylinder. The Glenn L. Martin Co. got a contract in 1946 for 10 such rockets from the Naval Research Laboratory, with the motors to be developed by Reaction Motors, Inc.

The Viking is approximately 44 ft long and 4 ft in diam. Its weight without fuel is 3,000 lb, with fuel, 15,000. The thrust engine develops 20,000 lb, bringing the rocket to a maximum speed of 4,000 mph.

The V-2 used vanes directly in the jet stream to obtain control from the main powerplant. However, builders of the Viking felt that a gimballed rocket motor was a superior approach. Control for the motor's position comes from a gyroscope with differential transformer pickoffs. The 400 cps signal from these pickoffs is demodulated, amplified, and fed to an electro-hydraulic valve. Movement for the motor then takes place though hydraulic cylinders.

Operation of the control tabs to counter roll is through hydraulic actuators controlled by solenoid-operated valves. The third system, utilizing hydrogen-peroxide-fired jets, uses solenoid valves in the fuel lines of the jets as control actuators. Relays operate the valves.

The author states that the most economical and convenient means for studying the performance of this system was through phase-plane representation, although simulation on a REAC computer was attempted (and considered a poor use of the machine's time). Lead circuits in line with the relay reduced dead zone.

The author's conclusions are that more time spent on simplified test procedures, and better packaged and more easily serviced components, would have greatly assisted the program.

Analysis Verified

From "Dynamic Response Analysis of an Air Heater Temperature Control System", by Leslie M. Zoss, Norman W. Gollin, and Robert I. Edelman, Taylor Instrument Cos., ASC Christmas Symposium, 1955.

Anyone who finds himself in the position of "selling" the dynamic analysis of control systems might do well to arm himself with a copy of this paper. It describes the results of experiments made to check the accu-

racy of calculated transfer functions of an air heater temperature control system. The authors say that had the results of the calculations been considered during the design of the control system, a better product would have resulted.

Experimental and analytical results are given for three tests. They show the influence of the position of the sensing element, of the type of sensing element, and of the type of transmitter. Frequency response of the system and control elements are shown.

The system under test aimed at providing constant temperature and humidity air to a dryer. A thermal bulb measures the dry bulb air temperature after a filter and sends temperature readings along via a pneumatic transmitter. The signal operates a recording controller.

For the experiments, a pneumatic sine wave generator was used to operate the valve motor that controls steam flow to the heater. Two recorders, one reading the sine wave input and the other the output of the temperature bulb's transmitter, provided system response information.

After discussing the equations derived to describe the system, the authors discuss their findings and their calculations. Here we find the somewhat disturbing statement, "Actually, no revolutionary discovery has been made, nor has anything been done analytically or experimentally that probably could not have been predicted by an experienced control engineer." This statement is worth a little thought. Surely the derivation of the equations required quite a bit of experience, or at least a thorough knowledge of each component's thermal properties. Could the man capable of making such an analysis also be able to predict (with an accuracy near that of the calculations) the effect of system variation? As the authors state, economy and quality are the objectives of the control system designer. But the economy and relative quality of the "educated guess" and the "let's-try-it-and-see" techniques must be compared with the cost of the quality analysis. Also, a set of linear equations is likely to be worthless for another setpoint. How much per setpoint calculation? These questions, which form the core of the conflict between tinker and thinker, are not answered for this study (as indeed, the answers will vary from case to case). While the authors have fought a nice skirmish with the economics question, there is more to be said.

NEW BOOKS

Transform Library

Space in last month's issue prevented inclusion of the following excellent bibliography prepared by Prof. Thomas J. Higgins of the University of Wisconsin's Electrical Engineering Dept. The list was to have accompanied his review of *Tables of Integral Transforms*, by A. Erdelyi of Cal Tech. Professor Higgins concluded his review with the observation that Erdelyi's volumes do not contain tables of Laplace transforms. The following books, the Professor declares, do have these tables.

1. *DICTIONARY OF LAPLACE TRANSFORMS*, J. Cossar and A. Erdelyi, Admiralty Computing Service, London, England, 1944-1946. Not generally available; it is well-encompassed in Volume I.
2. *FORMULAIRE POUR LE CALCUL SYMBOLIQUE*, N. W. McLachlan and P. Humbert, Gauthier-Villars, Paris, France, edition 2, 1950, 65 pages. The s-multiplied form of the LaPlace transform is tabulated.
3. *SUPPLEMENT AU FORMULAIRE LE CALCUL SYMBOLIQUE*, N. W. McLachlan, P. Humbert and L. Poli, Gauthier-Villars, Paris, France, 1950. The s-multiplied form is tabulated.
4. *TABELLEN ZUR LAPLACE-TRANSFORMATION UND ANLEITUNG ZUM GEBRAUCH*, G. Doetsch, J. Springer, Berlin, Germany, 1947, 185 pages. Contains inclusive tables; in a paper cover, convenient to carrying in pocket or briefcase.
5. *SPRAVOCHNIK PO OPERATSIONNOMII IS CHISLENIIU (HANDBOOK OF OPERATIONAL CALCULUS. BASIC THEORY AND TABLES OF FORMULAS)*, V. A. Ditkin and P. I. Kuznetsov, Gosud. Izdat. Tekh.-Teor. Lit., Moscow and Leningrad, Russia, 1951, 225 pages. Contains a lengthy table of transforms, well-encompassed in Volume I.
6. *OPERACIONNOE ISCISLENIE I EGO PRILOZENIYA K ZADACAM MECHANIKI (OPERATIONAL CALCULUS AND ITS APPLICATION IN MECHANICS)*, Gosud, Izdat, Tekh.-Teor. Lit., Moscow and Leningrad, Russia, edition 2, 1951, 432 pages. Contains a lengthy table of transforms, well-encompassed in Volume I.
7. *DIE ZWEI DIMENSIONALE*

NEW BOOKS

LAPLACE-TRANSFORMATION EINE EINFUHRUNG IN IHRE ANWENDUNG ZUR HOSUNG VON RANDWERTPROBLEMEN NEBST TABELLEN VON KORRESPONDENZEN, D. Voelker and G. Doetsch, Verlag Birkhauser, Basel, Switzerland, 1950, 259 pp. Has a 93-page table of double Laplace transforms, unavailable elsewhere.

8. *OPERATIONAL CALCULUS BASED ON THE TWO-SIDED LAPLACE INTEGRAL*, B. van der Pol and H. Bremmer, University Press, Cambridge, England, 1950, 415 pages. Has an excellent, 37-page table of two-sided Laplace transforms, unavailable elsewhere.

Control for Chemical Engineers

Automatic Process Control for Chemical Engineers. *By Norman H. Ceaglske, Professor of Chemical Engineering, University of Minnesota, 6 by 9 in., 228 pp. Published by John Wiley & Sons, Inc., N. Y.* $6.75.

In an interesting preface, the author of this undergraduate text mentions that the book began while he was working with Prof. Don Eckman (Control Engineering's August 1955 personality). Although built on the needs of chemical engineering curricula, the approach taken by the author has many fine features for the practicing engineer in search of a basic text. The first two chapters provide an introduction to contemporary automatic control in the process industries, including a good selection of illustrations showing standard process instruments. Up to page 65 it's easy and fast-reading. From that point on we have math. The reader is expected to be roughly on junior or early senior level, so the material begins simply enough. A brief and clear exposition of the Laplace transform is given in a few pages, with the rest of the chapter devoted to the derivation of equations that describe system components.

The fourth chapter shows how, by standard methods with differential equations, the response of various components to various signals can be computed. Chapter 5 shows how the Laplace transform simplifies the quest for transfer functions and shows how solutions are found for complete systems. The sixth chapter goes into the significance of frequency response. A nice rounding out of analytical meth-

ods, including mention of graphic analysis techniques, makes up the last chapter.

Physics Roundup

MODERN PHYSICS, A TEXTBOOK FOR ENGINEERS. *By Robert Sproull, Associate Professor of Physics, Cornell University. 6 by 9 in., 491 pp. Published by John Wiley & Sons, Inc., N. Y. $7.75.*

Although this book was prepared with the author's sights on a "round-up" physics course taught at Cornell to undergraduates and industry groups, the unaffiliated reader was also kept in view. While those aspects of modern physics likely to have the most importance to the average engineer (semiconductors, automatic analyzers, and applied nuclear physics) are emphasized, about half of the book provides general background. Descriptions of the apparatus used to measure various effects appears often, providing interesting instrument information. The book has a very wide scope, giving it reasonable value as a reference piece.

The first chapter takes us through the basic particles, electron, proton, neutron, the devices for measuring them, and the effects of velocity. The second chapter talks about assemblies of particles and the motions taking place therein. Chapter 3 tells us how the atom is held together. Chapter 4, with its discussions of X-ray spectra, black body radiation, electron defraction, and neutron defraction, gets right into home territory as far as a number of industrial measuring devices are concerned. A little later, almost 100 pages are devoted to solid state devices.

All told, the book looks like a fine balance between gadgetry, theory, details, and scope.

Transformer Design

ELECTRONIC TRANSFORMERS AND CIRCUITS, 2ND ED. *Reuben Lee, Westinghouse Electric Corp., 6 by 9 in., 360 pp. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. $7.50.*

This is a new edition of a well-accepted reference book first published in 1947. It starts with the fundamental attributes common to all transformers. Then, chapter by chapter, it discusses the design factors that are important in special types of transformers. Interspersed chapters deal with rectifier performance, and amplifier and pulse circuit that depend on transformer characteristics.

Only the basic mathematics of trans-

former design is included, and there are few mathematical proofs. But the book is replete with design charts and graphs that have been calculated from the mathematical bases. The author claims "good general correspondence between the graphs and experimental tests. . . . the graphs [for pulse transformers] predict wave shape with fair accuracy, but to predict exactly all the superposed ripples would be impracticable."

Chapters 9 and 11, on "Magnetic Amplifiers" and "Pulse Circuits", have been added since the first edition.

Managing Electrons

ADMINISTERING A CONVERSION TO ELECTRONIC ACCOUNTING. *Harold Farlow Craig, Harvard Business School, 5½ by 8 in., 224 pp. Published by Harvard University, Boston, Mass.* $2.50.

Electronic accounting systems offer solutions to the increasing volume of paper work and the short supply of suitable office personnel, and to the problems of reducing the cost per unit of accounting operations and meeting new needs for accounting and statistical data. But the conversion of procedures from manual to electronic are not easy tasks. Businessmen have found that while the new systems solve some problems, they are apt to create new ones. The conversion period can bring problems of stubborn employee resistance, confusion in routine work, and disruption of supervisory jobs.

This book presents a case study of a conversion to electronic accounting in a large insurance office. The particular conversion studied was skillfully administered and proved to be very successful. The study is particularly concerned with the administrative aspects of the conversion to the new accounting systems, rather than the technical aspects. This emphasis takes into account those things that were of major importance to the administrator responsible for the conversion.

Part I contains some background material on the company concerned, together with a detailed description of a department immediately before and immediately after the conversion to the new procedures.

Part II of the study contains clinical accounts of incidents of administrative behavior during the conversion period.

Part III contains Professor Craig's observations on the evidence presented in Parts I and II and his conclusions and recommendations arising from the

study. Sixteen significant questions should assist executives in understanding the administration of a conversion to electronic accounting.

Quizzes and Answers

Professional Engineer's Examination Questions and Answers. *William S. LaLonde, Jr., 5½ by 8 in., 462 pp. Published by McGraw-Hill Book Co., Inc., 330 W. 42d St., New York 36, N. Y. $6.50.*

This book will give candidates for engineering licenses an excellent idea of what the real examinations are like and what they need to know to pass. It contains over 500 questions selected from recent examinations for Professional Engineer License, Land Surveyor License, and Engineer-in-Training Certificate. For every question there's a detailed answer of the type examiners accept and credit.

The questions cover all major phases of professional engineering examinations: fundamental engineering; chemical, civil, electrical, and mechanical engineering. Many of the examples are composites of the more complex questions found in professional engineering examinations all over the United States. Thus, no matter what the license candidate's field of engineering is, or in what part of the country he will take his exam, this book will serve him well.

The author has prepared many license examinations. He is a licensed professional engineer, and chairman of the Dept. of Civil Engineering at Newark College of Engineering.

Missile Control

Guidance. *Arthur S. Locke, Vitro Laboratories, and others at the Naval Research Laboratories, 6 by 9 in., 729 pp. Published by D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N. J. $12.50.*

This is the first volume to appear in a projected series on guided missiles. The series is edited by Grayson Merrill and will cover subjects such as operations research, systems engineering, structures and design practice, aerodynamics, propulsion, armament, launching and range testing, as well as the material on guidance presented in this volume.

The subject is approached in a logical and thorough manner. Following an introductory chapter, essentially a definition of the guided missile problem, there are chapters on prior developments, terrestrial and celestial references, transmission of radio waves,

infrared, mathematics, servo system theory, tactical considerations, measurements of missile motion, detection and information gathering, target considerations, analysis of flight paths, pre-launching and launching, missile air frame, economic considerations, missile guidance systems, bandwidth studies (two chapters), simulation, computation and telemetry (all in one chapter) and the system concept.

As one reads the opening chapters, it seems that a thorough treatment of all pertinent factors is in store and that a convenient resume of the later and more complete analysis is being given first as a guide. Most every consideration entering the design is touched upon. The reader is informed of many problems that will arise in guided missile design, but for most problems only their generalities are discussed.

Chapter 2, on prior developments, is interesting, well written, and serves to set the stage for a discussion of more modern systems. Chapter 4, on transmission of radio waves, is essentially a descriptive review of the subject. The only really quantitative material is in the section on "Conductivity of a Gaseous Medium". It is unfortunate that security restrictions have evidently made it necessary to delete experimental data.

Chapter 6, "Mathematical Groundwork", presents an elementary version of the subjects needed in the rest of the book. The treatment is clear, concise, and is adequate to the purposes of the book. Chapter 7, on servo system theory, presents one method of servo design only. This is perhaps justifiable in a book of limited scope, but other methods should be listed and their advantages and disadvantages given. There is, in this chapter and in several others on bandwidth studies, guidance systems, and simulation, apparently no attention paid to noise problems. This would appear to be a serious omission, since many missile systems are designed almost wholly on the basis of the noise inputs.

Chapter 12, "The Analysis of Flight Paths", contains a very good elementary treatment of the basic navigation systems. It shows quantitatively the faults and advantages of each. The chapter could have been made even more valuable by a short treatment of methods of linearization, which would have enabled the discussion of more complicated cases.

R. B. Muchmore,
The Ramo-Wooldridge Corp.

WHAT'S AHEAD: MEETINGS

MARCH

Instrument Society of America, Conference on Instrumentation for the Iron and Steel Industry, Hotel Webster Hall, Carnegie Institute of Technology, and Mellon Institute of Industrial Research, Pittsburgh, Pa. Mar. 5-6

American Society of Mechanical Engineers, Aviation Division Conference, Beverly-Hilton Hotel, Los Angeles, Calif. Mar. 14-16

Institute of Radio Engineers, National Convention, Kingsbridge Armory and Waldorf-Astoria Hotel, New York. Mar. 19-22

American Society of Mechanical Engineers, Instruments and Regulators Div., Second Divisional Conference, Princeton University, Princeton, N. J. Mar. 26-27

APRIL

Special Technical Conference on Magnetic Amplifiers, sponsored by American Institute of Electrical Engineers, Institute of Radio Engineers, Instrument Society of America, Hotel Syracuse, Syracuse, N. Y. Apr. 5-6

International Exhibition on Instrumentation-Automation, Norwegian Industries Development Association, Royal Norwegian Council for scientific and industrial research, Abelhaugen Halls, Oslo, Norway. Apr. 9-22

American Institute of Electrical Engineers, Conference on Recording and Controlling Instruments, Bradford Hotel, Boston. Apr. 26-27

MAY

Instrument Society of America, Second National Flight Test Instrumentation Symposium, Hotel Texas, Fort Worth, Tex. May 6-9

Symposium on Reliable Applications of Electron Tubes, RETMA Engineering Department, IRE Professional Group on Electron Devices, and JETEC, University of Pennsylvania, Philadelphia, Pa. May 22-23

American Society for Testing Materials, Fourth Conference on Mass Spectrometry, Netherlands Plaza Hotel, Cincinnati, Ohio. May 27

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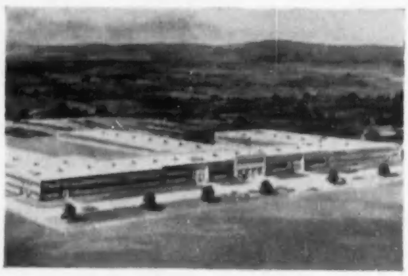

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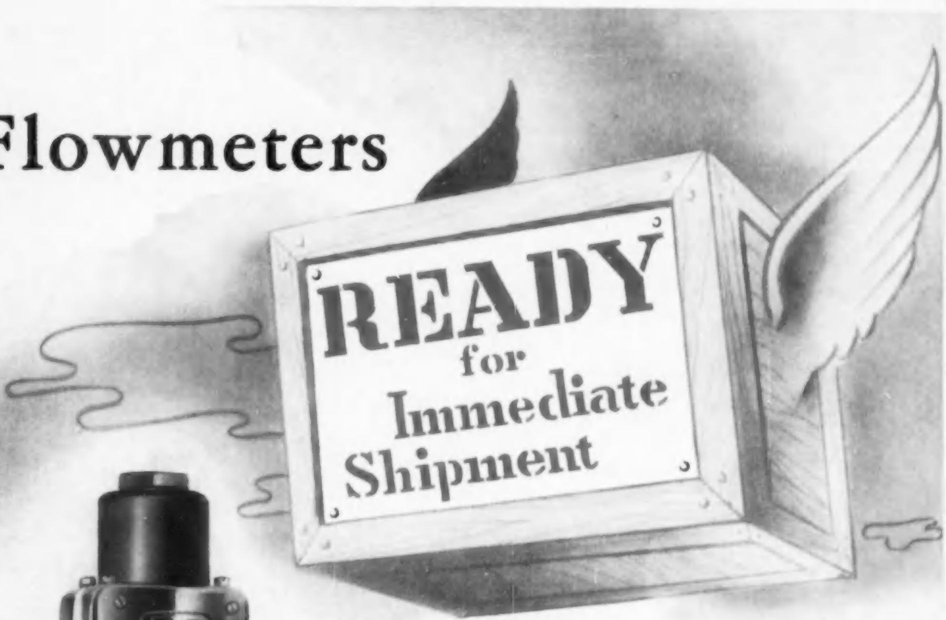

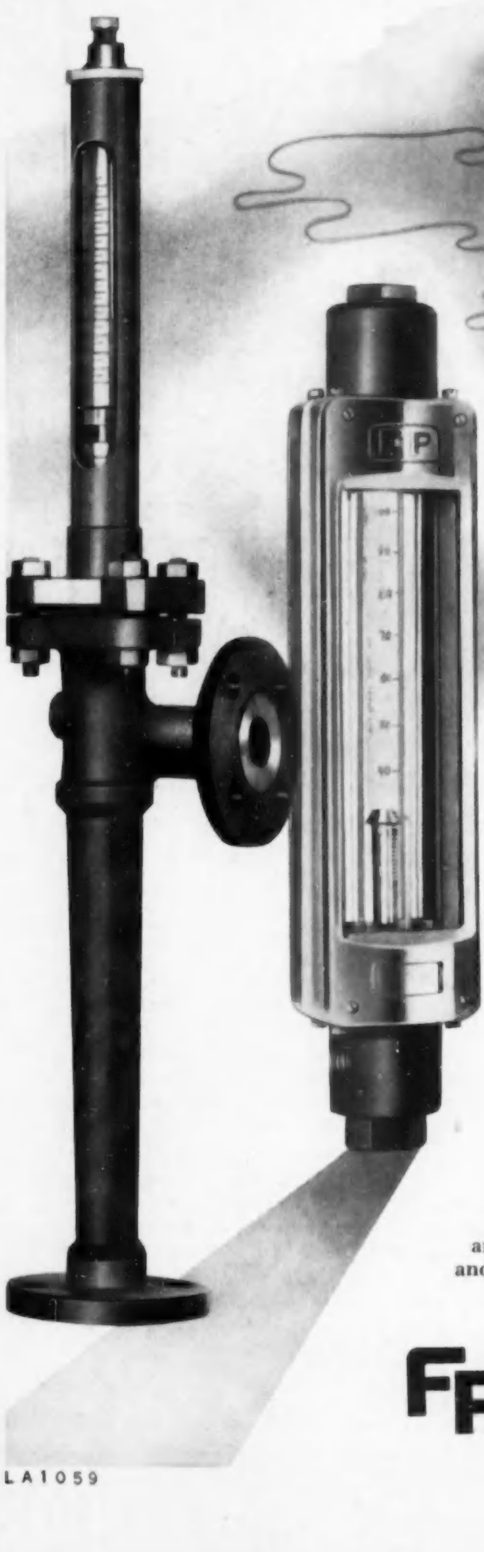

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